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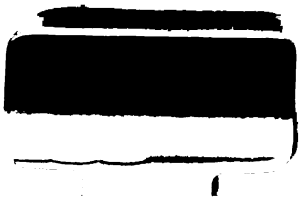

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TESTS FOR POWER-INPUT FOR OPERATING THE EQUIPMENTS AT THE LEAD AND ZINC MINES IN SOUTHWESTERN WISCONSIN

by

FREDERICK HENRY RICKEMAN

A Thesis Submitted for the Degree of

ELECTRICAL ENGINEER

UNIVERSITY OF WISCONSIN

1909

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The test which forms a part of this thesis was made by the writer for the Northern Electrical Manufacturing Company, of Madison, Wis., during the month of April, 1908, at Platteville, Wis., and at the property of the Empire Mining Company. The test was made for the purpose of ascertaining the power-input required for operating the mining company's entire equipment by one central motor or by several motors arranged for group drive or by individual motors.

A number of Northern direct-current motors were sent to Platteville and these were driven from the company's generators which were already installed in their plant. These motors were numbered #23411, #25369, #25233, and #24718, and were of different capacities. A Crosby steam-indicator #8427 was used for indicating the steam-engine and springs which had been checked for accuracy were used in it. A Weston voltmeter, double scale 0-150 and 0-300, #467, and a Weston ammeter 0-300, #8891, were used for reading volts and amperes. A recording Bristol ampere meter 0-150, #42, was likewise used for determining the input to the motors. The three above mentioned electrical instruments were checked and calibrated with Weston Standard

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Laboratory instruments, voltmeter #557, and ammeter #569, installed at the laboratory of the Northern Electrical Manufacturing Company. A Crosby planimeter #27463 was used for determining the mean effective pressure shown on the steam indicator cards. All speeds were taken with a stop-watch and a Starrett speed-indicator.

The tests on the different machines were made by driving them separately by belts operated by one of the motors previously mentioned. For the purpose of driving some of the apparatus, it was necessary to use a portable idler-pulley which consisted of an iron pulley 15" in diameter with a 12" face. This pulley rotated freely on a well lubricated steel shaft which was fastened at its ends in iron brackets supported from the two sides of one end of 12" X 12" wooden beam. It was necessary to use this idler with some of the apparatus because the driving pulley ran with a part of its lower surface below the floor or below the framework of some of the machines. The r.p.m. of the idler was low and its power-input small and almost negligible, but in all cases was deducted from the motor output in determining the power-input to the various machines which were tested.

The available space in the ordinary mill of a mining property for the placing of motors for testing purposes is

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very limited; there is very little spare floor-space and the center of the floor must at all times be left open for the free passage of the trucks for taking out the concentrates from the jigs. This made it necessary to elevate the motor above the floor, and in order not to interfere with the working operations of the mill, the motor was placed in position at night and kept there either all day or until the noon hour. The tests were therefore run either four or eight hours on all equipments in the mill. The tests of the hoist-motor were made for shorter periods. A number of tests were made on this motor because considerable trouble had occurred in connection with this hoisting apparatus since an overrated motor had at first been installed for operating the hoist. The hoist-motor which was used during the test was one which had been permanently installed before this test was undertaken. When the power-input for operating the Cornish Lift-Pumps was determined the motor was used which was permanently installed for operating these pumps.

All of the motors which were used when the test was conducted were Northern direct-current motors. They were of the plain-shunt type, compound type, and compound interpole type. For determining the power-input to the motors the impressed e.m.f. was read on the voltmeter and the armature amperes were read on the ammeter. The recording

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Bristol ampere-meter was likewise connected in circuit with the armature current. This latter instrument only registered approximate amperes because the recording needle was not sensitive enough to record all fluctuations. The records from this instrument however were very useful when used in connection with the volt-ampere readings for the purpose of constructing the time-ampere curves which are included within the pages of this report. When those machines were tested which had fluctuating loads, readings were taken very frequently during periods of fifteen and thirty minutes. During the tests on the other apparatus readings were not taken as often. At all the tests readings were taken throughout the entire periods of four or eight hours in order to discover the maximum peak loads.

The test motors were variable speed motors and where it was thought necessary the machines were run at different speeds, and readings then taken in order to determine the power-input required under such conditions of operation.

For purposes of determining the motor-output or the input to the driven machines it was necessary to determine the losses in the motors at the speeds they were operated when driving the different apparatus. For the purpose of calculating these losses readings were taken of the input to the motor armature when same was running unloaded at the

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speeds at which the armature was run when driving the different apparatus. The input to the motor at these speeds less the c^2r loss in the motor armature represented the losses for the different speeds due to windage and bearing friction and core-loss. There was a very slight error in determining the motor core-losses in this manner, since the field excitation for the same speed when running light and when running loaded was not the same. Such errors were so slight however, that for the purposes of this test the input as determined for the various machines tested represents accurately enough for commercial purposes the amount of power which will be necessary for operating similar apparatus.

The equipment at the Empire mine was chosen for making a test because it represented an installation which was more complete than any in the district at that time and because the mill was well constructed and the main line-shaft was in good alignment, thus furnishing a group of machines driven under conditions representing a loss in friction which was not excessive. In the majority of installations throughout the entire lead and zinc mining district of Wisconsin the mill construction is not as substantial as was that at the Empire property, and in many instances it was evident from the vibration which was manifest when the mill equipment was being driven that the main line-shaft was completely out of align-

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ment. A test with a steam indicator at one of the largest properties in the district disclosed the fact that the power required for operating its mill was approximately 20% in excess of the power which ought to have driven all of the machines which were belted to the center line-shaft. Inquiries from the engineer in charge of the plant afterwards brought out the fact that the ends of the two shafts, where they were connected together by means of a coupling, were several inches out of line when the two parts of the coupling were not bolted together. A line-shaft such as has been mentioned is in all cases supported by bearings placed on the tops of twelve or fifteen foot timbers spanning the mill-room at distances of about ten feet apart. In this particular instance it was only ascertained that the shafts were out of line between two bearings and it is probable that many of the bearings were out of line since the friction-loss was so much in excess of what it should have been with good alignment of all bearings. When it is borne in mind that the horse-power-input to the standard mill is approximately sixty-five or seventy-five horse-power, and that twenty per cent of this represents thirteen or fifteen horse-power-loss which might be occasioned by poor alignment of the supporting bearings, it may readily be appreciated what the loss in dollars will be at the end of a month or a year in a mill

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operating fifteen or sixteen hours per day. The results of this test disclose the fact that in such a mill as the Empire, where it was thought the conditions were good for economical operations, the friction-loss in the line shaft and belting may be accepted as being approximately twenty-five per cent or more of the horse power applied to said line-shaft.

The mill equipment consisted of machines of the standard type found throughout the Wisconsin district. Ninety per cent or more of the more recent equipments and the power and pumping plants in southwestern Wisconsin have been furnished and installed by the Galena Iron Works. Little criticism can be made of the jig and crusher installations together with the necessary screens and conveying elevators, because this part of the installation appears to work efficiently and is put up probably as well as occasion demands and the money invested pays for. The Mathey roaster, as it is called throughout the district, is also furnished by the above mentioned company and makes a satisfactory roast. Its efficiency could be improved with better and proper handling. The most important equipment at the majority of the mines is the pump installation. Some of the mines have installed underground, steam piston-pumps, and there are a few deep well plunger steam-head pumps. For handling the larger quantities of water, however, the old fashioned Cornish

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cross-head plunger lift-pump is used, and this type of pump has been installed at the majority of the mines. Its economy of operation is much better than the underground steam-pump, or the steam-head deep well pump. Such a type pump was installed at the Empire and it was of the geared type driven with a belt from a direct-current motor.

Usually only two or three jigs are installed in the mills in the Wisconsin lead and zinc district. The Empire mine had five jigs, three of which had seven cells each, one had five cells, and the other four cells. Two slime-tables were operated at this property and there are only three or four other mines in the district which operate tables. Hoisting was done with an electric-hoist operating a bucket larger than the average bucket used in the district. A large, belted compound compressor is employed at this mine for furnishing air for the air drills, and piping is led from the engine-room for a distance of approximately twelve hundred feet before it descends underground for piping to the drills.

In addition to the mine drainage-pumps already mentioned, there is installed at every mill a pump for supplying the water for the jigs and the crushers. As separation of the ore from the broken rock is produced by the gravity process considerable water must be kept flowing along with the crushed material. For this supply the mine water which is

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first pumped from the mine is emptied into a pond and from here it is pumped into the mill and led into the jigs and other machines. This water is used over and over again, flowing back into the pond where much of the fine silt is deposited. For handling this water-supply a belted centrifugal pump is used. These pumps invariably run at high speed. The silt does not appear to cause much damage, as the pumps to be seen in operation very seldom give evidence of any trouble. Such a pump was tested at the Empire, and the data will be found discussed further on.

All concentrating mills operate with elevators for conveying the broken rock and ore to the different jigs and crushers. The average number operated is four or five. The tailings-elevator conveys the broken stone from the last jig away from the mill building, and for this purpose it is much higher than any of the others. When the quantity of chat or broken stone which forms the refuse of the crushed rock accumulates into huge piles, these tailings-elevators are built higher so that the stream of rock and water may have sufficient slope to run off. Those mills which are fortunately situated on the side of a slope require fewer elevators. At the Empire mine there were five elevators. Only one was tested which was a double belt elevator, as the pulleys for driving were up very high and not easily accessible on ac-

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count of the many other belts and shafts.

A few of the Wisconsin zinc mines do their rock drilling with electric rock drills at a great saving of power. The majority, however, employ either a belted or steam-driven air-compressor. At the Empire mine a large compound Ingersoll Rand belted compressor is operated. No accurate test was made upon it. An indicator-card of the engine was taken when operating the compressor and the horse-power-input determined. The number of drills which were connected up was known, but as the connecting pipe line was over half a mile long, there was no plan available for determining how many drills were operating simultaneously. The compressor-input required for operating air-drills of different sizes is already well known, and therefore a test was not considered necessary at Platteville.

Many of the mines have their own furnace-rooms which contain the roaster for changing the iron sulphide ore into an iron ore which has magnetic properties, in order that the zinc concentrates may be rid of the iron ore by means of a magnetic separator. The furnace room contains this separator and the necessary conveying apparatus and a small rock crusher for conveying the concentrates to and from the furnace and magnetic separator. The small crusher is used for

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crushing some of the broken ore into finer particles in order that it can be handled more efficiently by the roaster and separator. When roaster equipments are installed they are operated by motors stationed in the roaster house in an isolated room. For determining the power-input to the roaster plant at the Empire, readings were taken on the installed motor for electrical input to it and deduction made for friction/and core losses for the speed it was operated at.

At a number of the mines in the district other shafts than those at the mill room are used for getting out ore from underground and sometimes the mines operate both such a shaft and the one at the mill room. Beacuse such a distant shaft would require a separate steam installation or a long inefficient steam line, electric power is used in them at the hoists, and the tram-way leading from the shaft to the mill is for like reasons operated by an electric motor. The Empire plant included such a tram-way and a separate motor is installed in connection with it for its operation. At some of the plants the hoist motor also serves to operate the tram-way, but where hoisting is done at a rapid rate such arrangements are not economical ones.

The largest engine which the writer saw in the entire Wisconsin zinc district is installed at the Empire plant. It is a Bates Corliss 18 X 48 equipment, and was practically

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new when seen. Its main belt ran over a pulley on a short countershaft which was belted to a friction-clutch pulley to the main line-shaft. From the main shaft friction clutch pulleys also operated the compound belted compressor and a 100 K.W. Northern generator. This generator supplied all electrical power for operating the motors installed. No test was made for power-input or efficiency of this dynamo. A number of indicator-cards were taken from the Corliss engine, and from this was determined the power-input to the line shaft for operating the mill as a single group-drive.

After the individual machines in the plant had been tested the precise power-input to all of them was added, and this sum subtracted from the input required to drive the equipment when engine driven gave a very close approximation of the friction loss in the line shaft and belting.

There was also installed at the Empire mine a small slide-valve engine, which operated a belted 40 K.W. Northern generator from which electric power was obtained during the hours when the large engine was closed down. There was no test made on this smaller electrical equipment.

On the following pages there is a list of all the apparatus comprising the entire equipment of the Empire mine, with enough data to enable one to make comparisons with equipments in other parts of the Wisconsin lead and zinc dis-

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trict. The Empire plant has a rated capacity of one hundred tons per eight or ten hour shift. It is probable that by speeding up the various machines more tons of rock than that stated can be run through the mill, but such speed would probably not allow as good separation to be made in the jigs and wear and breakage would be increased very considerably. The furnace room with its single roaster is rated at a capacity of twenty tons of concentrates per twenty-four hours. At the present time there are one or two plants in the district which have installed two roasters, thus enabling the property to handle the concentrates from a one hundred ton mill when working two shifts per day.

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STEAM ENGINE TEST

On sheet No.II are tracings of the steam-indicator cards and on sheet No.III is tabulated the data on the Bates-Corliss engine. When the tests were made there was a misadjustment of the clutch pulley controlling the generator and it could not readily have been unbelted, and the engine running as empty was indicated when running the generator without load. This condition is designated in the tabulation as "A". When an indicator card had been taken with the engine loaded thus, the mill was started and after it had been running for forty-five minutes another indicator card was taken. Another card with a similar load on the engine was taken several hours afterwards. The average horse-power input to the line-shaft when operating the mill equipment was 83.8 horse-power. The engine driving the unloaded generator and the loaded mill is referred to by the letter "B" in the tabulation. The load referred to by letter "C" consisted of the unloaded generator, the loaded mill and the loaded belted compressor. The compressor load was thrown onto the engine by means of a lever controlling a clutch pulley. The compressor was furnishing air for five 2-3/4 in. air drills when the indicated load on the engine was taken. If all five were operating simultaneously each drill registered 77.5/5 horse-power or 15.5 horse power. It is probable that less than

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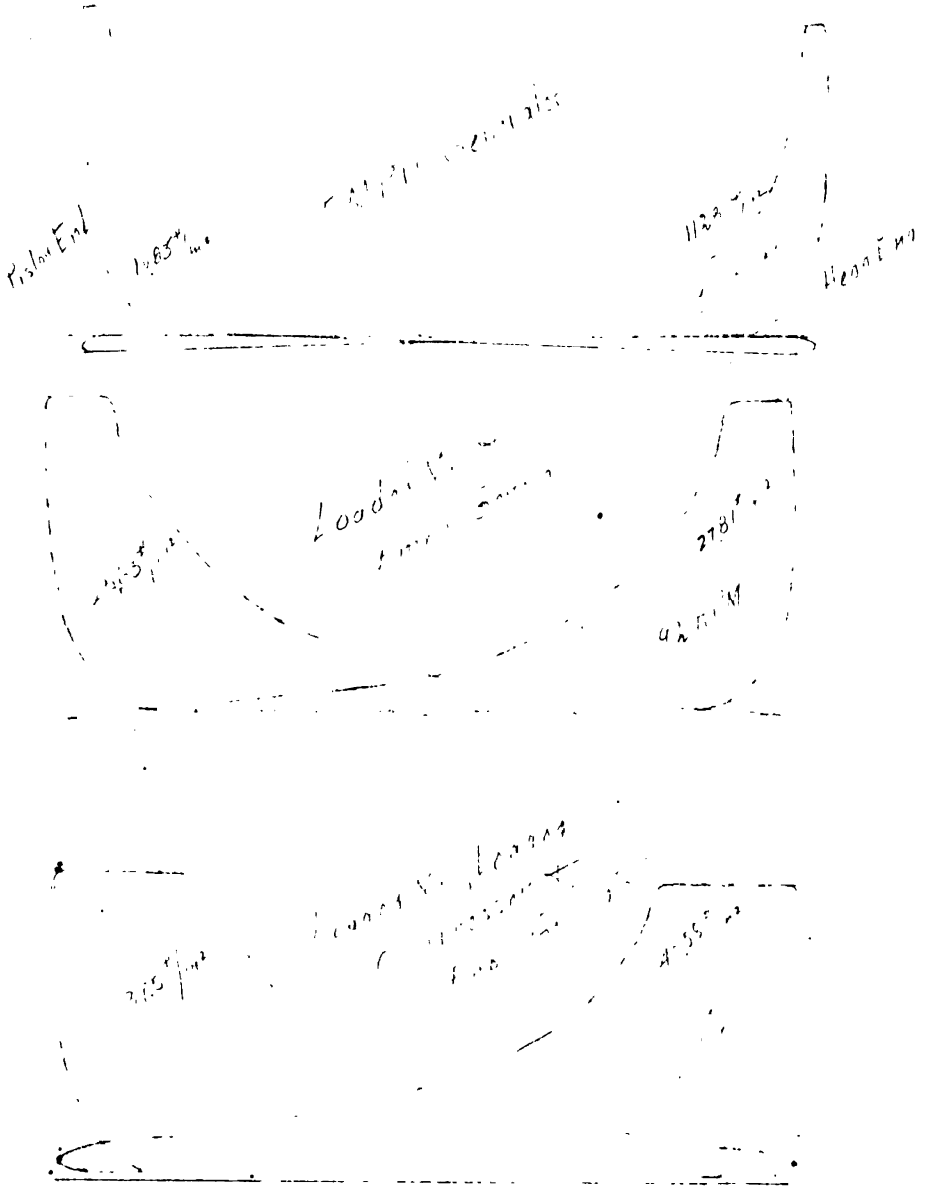

Sheet II

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Sheet III

Indicated Horse-Power Loads

Reading	Time - P.M.	Diam. of Cylinder, In.	Length of Piston-Stroke, In.	Number of Strokes Per Min	M.E.P.	L.A. ÷ 35000 Head End	L.A. ÷ 35000 Piston End	Empty Generator	Loaded Mill + Empty Generator	Loaded Mill + Loaded Compressor	Diam. of Compressor Empty Generator	Strokes P.M. of Compressor Air Cylinders, In.	Pounds Pressure per In² Comp. Air	Load on Engine	Calculated H.P. Necessary to Operate Mill with Motors	H.P. Mill-Input from Indicator Cards	H.P. Compressor Input from "	Total Indicated H.P.	Total H.P. Consumed by Line Shafting & Belting	Percent Power Loss in Shafting
1	1 15	18	48	92	10.85 11.28	.0308	.05	A.	B.	C	10 16			A				62.77		
2	2 00	"	"	"	25.65 27.91	"	"				"			B	63.2	84.7		147.5	21.49	25.3
3	2 30	"	"	"	39.5 40.58	"	"				"	135	82	C			77.5	225.1		
4	3 00	"	"	"	11.87 11.58	"	"				"			A	"			65.87		
5	4 00	"	"	91	25.86 28.06	"	"				"			B	"	82.9		148.8	19.7	21.9

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Sheet III

Indicated Horse Power Loads

Reading	Time - P.M.	Diam. of Cylinder, In.	Length of Piston Stroke, In.	Number of Strokes Per Min	M.E.P.	LA ÷ 35000 Head End	LA ÷ 35000 Rod End	Empty Generator	Loaded Mill + Empty Generator	Loaded Mill + Loaded & Empty Generator	Diam. of Compressor Air Cylinders, In.	Strokes P.M. of Compressor Pistons	Pounds Pressure per In² Comp. Air	Load on Engine	Calculated H.P. Necessary to Operate Mill with Motors	H.P. Mill Input from Indicator Cards	H.P. Compressor Input from "	Total Indicated H.P.	Total H.P. Consumed by Line Shaft	Percent Power Loss by Belting
1	1:15	18	48	92	10.85 11.28	.0308	.05	A.	B.	C	10/16			A				62.77		
2	2:00	"	"	"	25.65 27.81	"	"				"			B	63.2	84.7		147.5	21.49	25.3
3	2:30	"	"	"	39.5 40.58	"	"				"	133	82	C			77.5	225.1		
4	3:00	"	"	"	11.87 11.58	"	"				"			A	"			65.87		
5	4:00	"	"	91	25.86 28.06	"	"				"			B	"	82.9		148.8	19.7	21.9

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five drills were operating when the indicator-card was taken, as a 15.5 horse power input to the compressor for operating a 2-3/4 inch air drill is very low.

The data on sheet I, referring to the input to the machines comprising the mill equipment which required an engine output of 83.8 horse power, indicates that an input of 63.21 horse-power will operate the same if there by no friction in the transmission system. The difference between 83.8 horse power and 63.21 horse power represents a loss of 20.59 horse power which was occasioned by driving the equipment from the line shaft. The tests on the different machines when motor driven and when driven from the line shaft were made for similar conditions of operation; the same grade of rock and ore were being milled and the tonnage was approximately the same. Every machine was tested by being motor driven, except some of the elevators and these are so nearly alike and run under such similar conditions that the calculations for their horse-power-input closely approximates the exact power-input.

A loss of 20.59 horse power in transmitting power to a system which requires only a 63.21 horse power input represents a loss of 32.5 per cent, or if 83.8 horse power is required to operate a plant by belt drive from a central shaft line, a loss of 24.5 per cent of such amount is indi-

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cated by these figures as being lost in belt and shaft friction.

The line shaft which drives the equipment which was tested is approximately sixty-five feet long, and is the average length of the shafts in the other plants. As stated before they turn about in bearings which are placed about ten or twelve feet apart. Their speed in r.p.m. is low and the same averages about one hundred ninety or two hundred revolutions per minute. Each shaft carries a dozen or more wood and iron pulleys. And about them run rubber belts eight and ten inches wide. On either side of the line shaft and from eight to twelve feet below are the jigs and crushers and centrifugal pump. Likewise on either side, but some distance above are situated the pulleys which operate the belt elevators. The belt pull is fairly evenly divided on both sides of the line-shaft and the large losses in friction are not a result of uneven pull. Some of the belts are quite long and the belt tension is in most cases too great. As none of the separate machines require a greater input than eight or nine horse power, it is not necessary that the belts be as taut as they are. While the speed is quite low, yet the belts are sufficiently wide to easily transmit sufficient power when not stretched as taut as they are in all the mills

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which the writer has visited. In a number of places it took several men, and one wielded a crowbar, to take off from a pulley an eight inch wide rubber belt not over twenty-five feet long. This taut belt tension is the cause of large friction losses, and it also results in wearing out the belts in much shorter periods than they would wear out, if they were run with more slack.

Indicator cards taken on the mill engines in two other places also indicated that the frictional losses in the belt drive were very large. It has been the experience of investigating engineers that large proportionate losses occur in friction losses in all systems where much shafting and belting is employed in driving machinery. Such losses are inherent in the transmission systems in those machine shops where drive by belts and shafts is still practiced. In the shops there are numbers of line shafts and counter-shafts with their driving belts. In the mills on the mining properties, however, there is only one central shaft and no counter-shaft and the losses need not be as large as those found where tests have been made, if more care were taken in installing the line shaft and its belting. At one plant indicator-cards showed that sixty-five per cent of the power input necessary to operate the mill equipment was necessary to operate the same equipment without rock or water passing into or out

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of the machines. Proper alignment of all machines and all shafting on the different machines will also result in very much lowering the required power-input for operating many of the equipments in the mining plants in southwestern Wisconsin.

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FURNACE ROOM EQUIPMENT TEST

The roaster equipments in the lead and zinc district usually have a separate motor installed for operating the plant. Such methods of operation have proved very satisfactory. The roaster plant is more conveniently located at some distance from the mill and the motor drive overcomes the necessity of transmitting with a long shaft-line or with rope transmission. In some instances a separate steam power plant would be the most economical drive if the motor system could not be employed. There is always a large amount of dust in the air when roasting is being done and motors are usually protected as much as possible from such unfavorable conditions by being stationed in a small room set off in a part of the roaster room. Such rooms are not dust-tight, but if the door communicating with the furnace room is kept closed and the windows to the outside kept open, the running conditions for the motor may be maintained quite satisfactorily. At present direct-current motors only have been used for operating these plants in Wisconsin; when alternating-current motors are used it will not be so necessary to keep the dust from the motor.

At the Empire plant a Northern, shunt motor, # 18283,

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1200 r.p.m. and rated at twenty horse power, was belted to the line shaft driving the equipment for roasting the ore. All of the motors which were seen in operation in the district for this service are too large. Many of them are twenty horse power motors and in one instance a twenty-five horse power motor had been used for operating a standard roasting equipment, such as was installed at the mine where this series of tests had been made.

A number of readings were taken on the above motor while the roaster plant was operating under normal conditions. The input to the equipment was determined by deducting the c^2r losses and the frictional and core losses of the motor from the total input to the motor. The average input to the furnace room equipment was in this manner found to be less than six horse power. At other plants the input to the various motors examined while operating roasting plants was between seven and ten horse power. For the purpose of obtaining economical operation of such roaster equipments as are being discussed, motors of a capacity not larger than ten horse power ought to be installed. Perhaps there are momentary overloads for short periods, when parts of the machinery become clogged in some manner, but since standard motors can operate with safety under a fifty per cent overload for thirty minutes, and under a twenty-five per cent

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Sheet IV

Furnace Room + Magnetic Separator

Reading	Time	Tons Concentrates per Day	Diam. of Roaster	Length of Roaster	Speed "	Type of Magnetic Ore Separator	Number of Magnetic Ore Separator	Width of Separator Belt, Inches	Length of Spiral Ore Conveyor from Furnace	Diam., Inches, of Ore Conveyor	No. of Belt Elevators	No. of Shafts + C. Shafts	No. of Pulleys - All Sizes	Volts	Armature Amperes	Total Watts Input	Watts Core Loss, Friction + Cap Loss	Watts Out Put	H.P. Input To Operate	
									Ft.	In.										
1	2 PM		5	26	.571	Cleveland	2	21	12	12	3	5	8	250	24	6000	1660	4340	5.8	
2	4 PM		"	"	"	"	"	"	"	"	"	"	"	"	25	6200	1662	4585	6.14	
3	5 PM		"	"	"	"	"	"	"	"	"	"	"	"	24.4	6100	1661	4439	5.95	
																			5.97	Ave.

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overload for two hours, motors of ten horse power capacity would be sufficiently large to operate these plants. In a small number of instances two furnaces have been installed in the roaster rooms and the auxiliary apparatus has also been likewise added to, and for such installations motors of greater capacity should be installed.

The test above mentioned was made Wednesday afternoon, April 8, 1908, and the roaster equipment was being operated night and day and was working at a rate approximating twenty tons of ore per twenty-four hours.

The above stated input did not include the energy consumed in the operating magnets. The Cleveland magnetic separator is the type used in the large majority of the plants in the district. This type of separator employs several revolving circular magnets above a conveying belt which carries the roasted ore. As the iron ore is attracted to these magnets and adheres to them it is scraped off by leather or brass scrapers at a place beyond the edge of the carrying belt, where it falls down and is wheeled away or disposed of in some other manner. The current to the energizing coils is regulated by means of a variable resistance.

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CENTRIFUGAL PUMP TEST

A No. 5 centrifugal pump which was operated in the mill by a belt from the line shaft was run by a Northern shunt motor #22689. The pump was run at the speed at which it is normally operated. According to Professor D. W. Mead's formula for the proper peripheral speed, the said speed was too high by 93 r.p.m., and it is evident from the low efficiency obtained that the pump is not adapted for the service which it is performing. The operating head is a low one, and if a proper pump of this type were chosen for the discharge indicated a very much better economy of operation would result.

For determining the number of gallons of water discharged a weir-dam was constructed and the water was discharged through it after being elevated to the proper head. The test was run just after the shut-down of the mill and the water pumped contained the same approximate amount of silt which the water held during operating conditions. A gallon of this water was weighed and there was nine and one-half pounds, showing there was 1.2 pounds of silt in every gallon of liquid handled by the pump. A number of readings were taken for the electrical input to the motor and for the

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quantity of water discharged. From the motor input was deducted its total losses and this result divided into the water horse power or the output of the pump figured for the discharge head gave the efficiency of operation. The discharge head included the loss due to friction in the suction and discharge pipes. The average efficiency as indicated inthe tabulation is 34.9 per cent. There is no reason why a centrifugal pump of more than twice this efficiency cannot be chosen for this service.

It is probable that the majority of these pumps which are at present installed in the other mills for similar duty are about as inefficient. They appear to be running at too great a speed and since many of them have been installed by the same concern it is probable that the same error has been made when installing them. This test was made at the company's mill Friday morning, April 17, 1908.

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Sheet I

Centrifugal-Pump, J. Traylor & Co.

Reading	Time	Diameter Impeller, In.	Width-Impeller, In.	Diam. of Disc. Pipe	Diam. of Inlet Pipe	Total Discharge Head, Ft.	Diam. of Pump Pulley, In.	Width of " "	" " Driving Belt	Speed of Impeller, R.P.M.	Peripheral Speed of Impeller Ft. per Min.	Gals. Discharge per Min.	Total Water H.P., Pump Output	Volts	Armature Amperes	Total Watts Input	Total Losses, Watts	Total Watts, Output, Motor	H.P. Pump Input	Pump Efficiency %
1	9⁰⁰	18	2.5	4.5	5	20	12	10	8	630	29.6	708	4.48	250	53	13260	3668	9692	12.8	.347
2	10⁰⁰	"	"	"	"	"	"	"	"	"	"	711	4.49	247	54	13340	3714	9626	12.9	.348
3	11⁰⁰	"	"	"	"	"	"	"	"	"	"	7105	4.49	250	53	13260	3668	9692	12.8	.348
													4.48			Average				.349

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TEST OF TRAMWAY HOIST

When determining the power required for operating this car hoist it was necessary to take readings of the volts and armature amperes of the motor permanently installed while operating the hoist, and to take similar readings for input to this motor when running empty at the same speed. In order to take no load readings it was necessary to ungear the motor from the hoist drum which wound up the cable fastened to the car. The efficiency of the hoist was not calculated. This factor depends upon a number of conditions which change daily. The alignment of the tracks, the amount of lubrication on the gearing, cable and car-wheels, the condition of the rails as affected by rain and sunshine, and the wind pressure, all influence the power input required for operating such a system. The tramway at the Empire mine is used for conveying the rock hoisted from the shaft down a slope to the mill. The car which conveys the rock holds three buckets of such stone and runs down a slope impelled by gravity. When there is a strong headwind the cars sometime become stalled. Ordinarily only enough power is required to pull the empty car from the mill up the slope. Sometimes however it has been necessary to pull up a loaded

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car and the time required to make either haul and the motor output necessary for such duty is indicated in the tabulation. Probably the average efficiency of a similar tramway hoist is about fifty per cent. Friction losses amount to a large proportion of the load, and if the speed much exceeded that shown the required input for operating the car would be considerably more.

In some of the plants where tramways are used for similar purposes one motor operates both the bucket hoist and the tramway car. The time required for hitching and unhitching the cable and making other alterations in some of the adjustments is however considerable, and where moderate speed at least is demanded two motors should be employed. Some of the tramways in the district are operated by steam-engines installed in the loft of the hoist houses, but in these cases, as also where bucket hoists are operated, there is always occasioned violent shaking of the entire framework.

The motor installed for operating this tramway hoist was a Northern fifteen horse power compound machine, and as indicated in the tabulation is at least fifty per cent larger in capacity than it need be. A seven and one-half horse power motor with the standard two hour, fifty per cent overload capacity characteristic would be sufficiently large for

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operating such a hoist. The total horse power hours input to a hoist motor is usually small because they are only operated for short periods. Where, however, machines are operated for long periods it is an important consideration to have motors of the proper horse power rating installed in order to have them operate efficiently. There are many instances in the district where the motors which are installed are much too large in capacity and these are consequently operated at much less than full load and therefore not economically. The serial number of the machine operating the tramway under discussion is #16143 and the readings were taken Wednesday afternoon and Saturday morning, April 15 and 18, 1908, and the data referring to this test is tabulated on Sheet VI.

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Sheet III

Tramway Hoist-Geared Motor Drive

Reading	Time	Length of cable	Weight of Cable-Pounds	Weight of Empty Car-Pounds	No. Cars Hauled Per Day	Ave. Weight of Complete Haul	Time Required for Loaded Car to Travel Down Tramway	Time Required to Pull Empty Car Up the Incline	Fall of Tramway	Average Number Inches per Foot	Time-Minutes Required to make Round Trip	Volts	Armature Amperes	Armature Amperes Empty	Watts Input	Watts Core Loss + Friction	Watts C²R Loss	Total Watts Output	H.P. Input to Hoist	Time Required To Pull Loaded Car Back
							Sec.	Sec.			Min.					Meter				Sec.
1	3 00	1050	405	1000		5700	90	115		80	3.5		235	23	5410	1200	265	4185	5.6	
2	3 30	"	"	"		"	"	120		"	"		"	38	8920	"	72.5	7647	10.2	
3	4 00	"	"	"		"	95	120		"	"		"	32	7520	"	52	6268	8.39	
4	4 30	"	"	"		"	90 ±	115					235	29	6820	"	42	5578	7.48	135
5	5 00	"	"	"		"	" "	115					"	41	9620	"	84	8336	11.2	135
6	11 00	"	"	"		"	96	"		80	3.5		236	23.2	5470	1180	27	4263	5.76	
7	11 30	"	"	"		"	"	"		"	"		"	38	8990	"	725	7738	10.4	

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SLIME TABLE TEST

On Sheet VII is tabulated the data and details of an input test for the operation of two slime tables installed at the Empire mine. The tables were manufactured by the Hendy Machine Company of San Francisco, and they are the only ones of that firm's manufacture seen in the district by the writer. There are very few tables in operation in the district. There is some prejudice against their employment in the district, and this fact is probably due to their efficiency as money makers not being appreciated. Their power consumption is very small and the attendance necessary to operate them is likewise not large. In some of the mills there is considerable fine ore going to waste and much of it can be saved by the use of these tables.

At the Empire mine the two tables were installed in a room separated from the equipment at the mill. They were operated from shafting driven from a belted motor which also furnished power for a centrifugal pump. In determining the power input to the tables a smaller capacity Northern motor than that one which was permanently belted to them was used. The output of the motor was determined as in the previous tests by considering the motor input and the losses in the

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Sheet VII

Hendy Slime-Tables, Hendy Machine Co. San Francisco, Cal.

Reading No.	Diameter of Tables-feet	Type of Driving Pulleys	Diameter of Pulleys, In.	Width of Driving Belts	No. of Volts per Minute	Max. No. Pounds Saved Per 9 Hours	Ave. No. " " " "	Volts	Armature Amperes-Two Tables	Total Watts Input-Two Tables	Watts Input-One Table	H.P. Input-To operate One Table				Ave H.P. Input per Table
1	10	Fly Wheel	14	2½	215	600	450	250	5.1	1275	637.5	.85				
2	"	"	"	"	"	"	"	"	4.7	1175	588	.78				
3	"	"	"	"	"	"	"	"	4.9	1225	613	.815				.815

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motor. Motor # 25369 was used for the test which was made Thursday morning and Friday afternoon, April 16 and 17, 1908.

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BUCKET HOIST TEST

Sheet No. VIII contains all data relative to the details of construction of this hoist and motor used for this test, and also the readings for power input, and curve sheet No. I shows a number of curves drawn with respect to the armature ampere current of the operating motor and the hoist horse power input and time in seconds.

When the test of this hoist was undertaken considerable effort was made to obtain as much information regarding the construction of the apparatus and the exact power requirements as possible, and the nature of the load was likewise to be determined with considerable accuracy. The Northern Electrical Manufacturing Company had furnished a motor for operating this hoist, and two or three armatures had been burned up when operating it. After several attempts had been made to have the motor operate properly it was discovered that a larger motor had been intended for that hoist than was geared to it. The motor tested as shown by the data referred to was the larger capacity motor and was sufficiently large. A voltmeter was used for determining the impressed voltage and an ammeter was connected in the armature circuit as was also a Bristol recording

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Bucket Geared Hoist.

Galena Iron Works Geared Hoist
Northern Electrical Manufacturing Company Compound Motor

Motor Number	25233
Motor Rating, Horse Power	40
" " Volts	220
" " Amperes	160
" " Speed, R.P.M.	400
Hoist Drum Diameter, inches	28
" " Width "	18
" Gear-wheel Diameter, inches	48
" " " Teeth, number	108
Motor-pinion Diameter, inches	9
" " Gear Teeth, number	19
Band Brake, width, inches	5
" " , thickness, " .	.187
" " , diameter bearing surface, inches	44
Rope Cable, Steel, diameter, inches	.625
" " " , length, feet	175
" " " weight, pounds	102
Bucket " "	200
Dirt Hauled, maximum weight pounds per bucket	1600
" " , average " " " "	1500
Haulage , maximum " "	1851
" , average " "	1751
Speed of Lift, maximum feet per minute	771
" " " , average " " "	675
" " " , minimum seconds per lift	16
" " " , Average " " "	17.5
Maximum Foot-Pounds per lift	523,975
Average " " " "	306,425
Maximum Horse Power, equivalent of one haul	36.8
Average " " " " " "	31.8
Volts during test	235
Armature Amperes, maximum	185
" " , average	120
Total Watts Input , "	27960
" " Core Loss + Friction	1728
" " C^2R "	1051
" " Output of Motor, maximum	32467
" " " " " Average	25181
Horse Power Motor Output, Maximum	51.5
" " " " Average	33.7
Efficiency of Hoist, Average	943

Final Test Made 4-18-08

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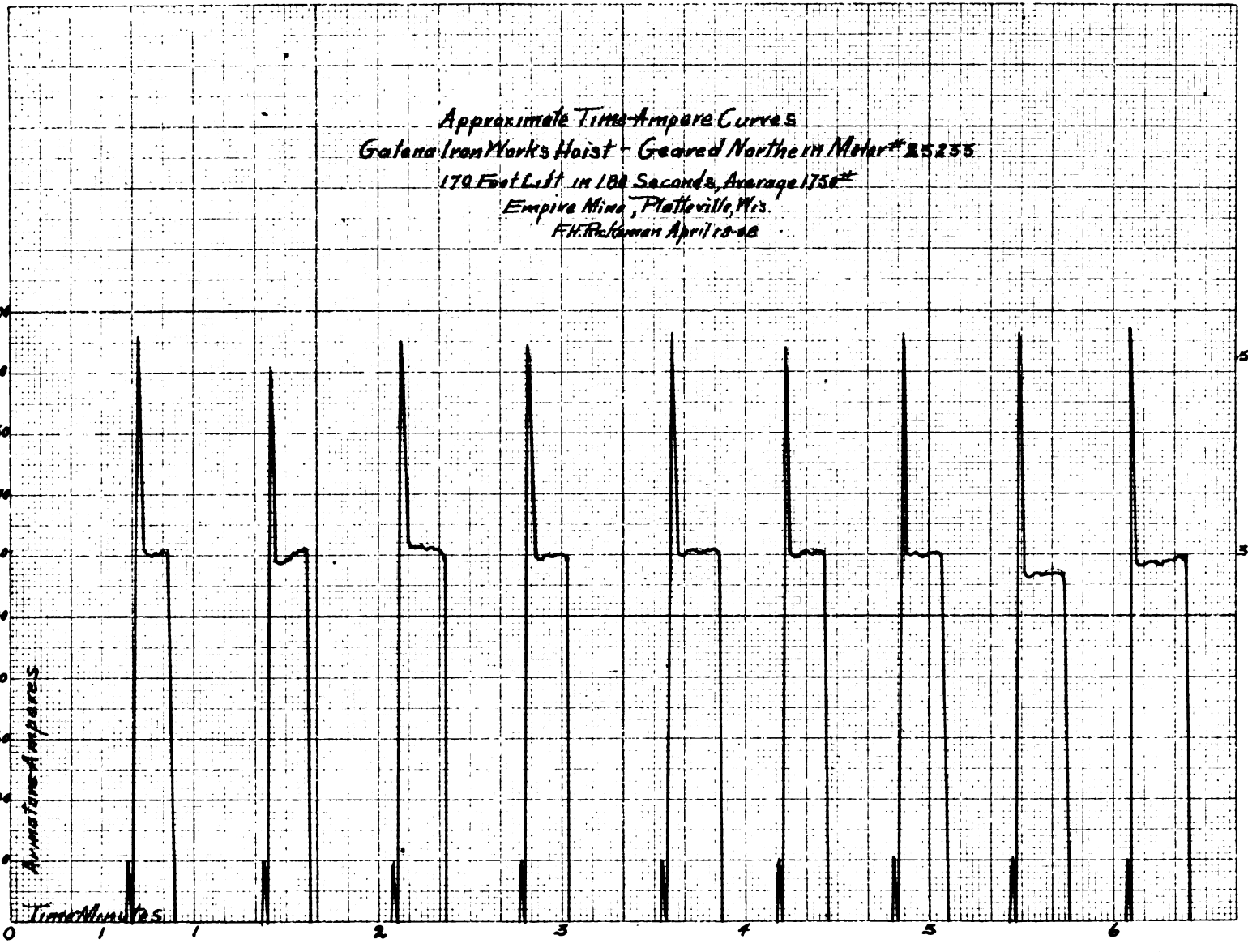
Curve Sheet I



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ammeter. Numerous readings on the portable ammeter were noted, and these were checked with the record left on the dial of the recording instrument. These readings and tracings combined with the voltmeter readings furnished sufficient data for constructing the curves, as shown on curve sheet No. I. Buckets were being lifted at the rate of two hundred and forty per eight hour shift. The total lift was one hundred and sixty eight feet, which was the distance from the bottom of the shaft to the top of the car, at the hoist platform, into which the rock was emptied. The average time taken to lift the bucket this entire distance was seventeen and one-half seconds and this average was obtained by computing a large number of readings taken on a stop-watch throughout the day. The size of the buckets operated in the district vary somewhat. At the Empire a large bucket was operated and the overall dimensions were thirty and thirty-two inches, the latter representing the height. The empty bucket weighed two hundred pounds, and the total weight of the cable with which the hauling was done weighed one hundred and two pounds. Only one-half of the cable's weight was used to determine the total weight of lift when computing the foot pounds of work performed. Much guessing is done at the different mines for determining the rock capacity of

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the hoist buckets, and with the same size bucket the weight of its contents varies greatly, owing to the difference in the nature of the rock and its ore contents. At the Empire mine it had been supposed that the average weight of rock hauled per bucket approximates twelve hundred pounds. A scale was taken to the shaft house and throughout several days every tenth haul was weighed. The maximum weight of a can of rock approximated sixteen hundred pounds and the average weight of rock hauled throughout the time that weights were taken was fifteen hundred pounds. A difference of two or three hundred pounds per bucket lifted makes a decided difference in the records of the tons of rock run through a mill in a days run, if the number of buckets lifted is taken as the guage for the run through the equipment.

The weight of bucket, its contents, and the cable, multiplied by the lift in feet, and this product multiplied by the number of such lifts made per minute furnished the figures represented in the foot pounds per minute output of the hoist. The output of the motor was determined as has been explained previously for the other tests described. The motor was ungeared from the hoist for obtaining readings for determining the core losses and losses due to friction. The efficiency obtained for the operation of the hoist av-

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eraged 94.3 per cent. This figure seemed high to the writer and for that reason a number of different sets of readings were taken and averaged with approximately like results. The efficiency of a bucket hoist is high because the moving parts travel slowly, and the total friction is consequently very little. A number of incline car hoists are employed in the district. The cars have a capacity of about three large buckets, and the speed at which the cars are pulled up is about the same as that of the bucket lifts. For the same amount of rock haulage the input in power to the bucket hoists would be very much less. There is always an excessive amount of friction to the average incline hoist at a mine, due to dragging cable and dirt on the tracks, and the conditions of the track and car-wheels, and bucket hoists can be more economically operated. At one of the mines in this district the bucket hoist is operated without any signals passing between the hoistman and the man below. In all other plants visited signals were given by a rope and bell.

The rating of the motor which was geared to the hoist at the Empire mine at the time this test was made was forty horse power and it did not heat excessively while operating at the maximum output for the hoist and hoistman. Since the test was run this motor has given trouble due to the armature burning out. It was operated by an incompetent man

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however, who always left one notch of the starting lever on, while changes of buckets were being made underground. In this manner this operator gained some in the time that it required to put the hoist into motion, but it proved to be very disastrous to the motor, since it caused the armature to overheat because it maintained a constant flow of current through the winding. Since a new man has been hired for operating the hoist no more trouble has occurred with this motor.

The curves for hoist input on curve sheet No. I illustrate the variation of load on the motor. At start a momentary peakload is thrown on which averaged about 51.5 horse power, but directly following this peak it is shown that the load on the motor and the input to the hoist average safe running conditions for the motor. Some variation in input to the hoist is indicated by the different curves and that is due to the unlike weights of rock hauled. A slight change in the time required to haul up a bucket is also indicated. This is due also to the changes in amounts of rock hauled, since the motor had a compound winding and consequently slowed down slightly with increase of load.

The operating motor was a Northern compound wound box or crane type machine of forty horse power rating at two hundred twenty volts, and operated normally at four hundred

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r.p.m. It was geared directly to the gear on the hoist drum, and the entire equipment is probably giving better service than any other hoist in the district; and it certainly is operated with a much better economy than the steam hoists as the high efficiency indicated in the data is never approximated by a small steam driven hoist. The final test was made on this hoist on April 18, 1908. As already stated readings of the motor volts and amperes and likewise readings for speed of bucket lift and weights were taken throughout a period of several days.

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TEST OF FIFTEEN INCH JAW CRUSHER

There is only one mining company in the Wisconsin zinc district which operates its jaw crushers with electric power. At the Ollie Belle Mine, near Benton, the jaw crusher and the roll crushers are driven from a shaft which is belted to an electric motor. Other apparatus is also driven from the same shaft and readings for the jaw crusher input are not indicated on any of the connected instruments. When the tests were to be made on the crusher at the Empire Mine a motor of a much larger capacity than was required was belted to its driving pulley, because it appeared that the power taken for operating this crusher would approximate ten or fifteen horse power. The manager and the superintendent of the mine were of the opinion that the power requirements would be about as stated above. We were all considerably surprised at the small average power input to the crusher. This crusher was normally operated by an eight inch rubber belt very tightly drawn over the operating pulleys. The jaw speed and the pulley speed was normally three hundred and thirty r.p.m., and if provision can be made for overcoming the high peakloads which occur on this type crusher it could be operated with a much lighter

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and narrower belt. The speeds of similar crushers throughout the district approximate the speed of this one. During the test the crusher was operated at a speed of three hundred and fifty r.p.m., as indicated on Sheet VIII, and this speed was apparently too high, as the operator complained that it did not work as well and that the rock was thrown up from between the jaws.

On Sheet VIII are shown the readings and calculations and the conditions of operation of this crusher when under test. During the shift that the test was made, ninety-seven tons of rock were run through in nine hours. Curve sheet II contains a curve plotted with respect to armature amperes of the motor and time and crusher horse power input and time. The curve was constructed to correspond to thetracing on the chart of the Bristol recording ammeter, and checked by volt and ampere readings on the portable instruments connected in circuit with the motor. If a longer curve had been platted it would appear very similar to repetitions of the one plotted. When running at normal speed the average input to the crusher was 3.5 horse power. The peakloads indicated eight horse power and fifteen horse power input, but these loads were only momentary ones. They were caused by very large rocks and by much fine material clogging between the

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Fifteen Inch Galena Iron Works Jaw-Crusher

	Reading	Time-A.M.	Armature Amperes	Field Amperes	Normal Working Crusher R.P.M.	R.P.M.-Crusher	R.P.M.-Driving Motor Pulley	Armature Amperes-Empty Motor	Volts	Total Watts Input	Watts-Core Losses	Watts-C^2R Losses	Watts Total Losses	Motor Output-Watts	H.P. Crusher Input
Crusher-Running Empty	1	7[30]	14	.92	350	330	855	7.6	3645	3645	1890	9.8	1900	1745	2.34
Crusher-Working, Are Ready	2	8[00]	21.5	.88	337	"	875	"	250	5370	1878	23.1	1901	3489	4.68
Max. Ready, Once in Two Minutes for Two Sec.	3	8[05]	52.5	"	"	"	"	"	"	13125	"	138	2016	11109	14.9
Max. Ready, Once in One Minute for Two-Sec.	4	8[10]	32.	"	"	"	"	"	"	8000	"	51.2	1929	6071	8.13
Below 17 Amperes for 50 percent of Time	5	8[15]	18.3	"	"	"	"	"	"	4580	1875	16.78	1892	2685	3.6
Below 16 Amperes for 25 percent of Time	6	8[20]	16	"	"	"	"	"	"	4000	"	15.82	1891	2108	2.92
Average Reading	7	9[00]	21.5	"	"	"	"	"	"	5380	1878	23.	1901	3479	4.66
"	8	10[00]	22.5	"	"	"	"	"	"	5624	"	25.3	1903	3721	5.
"	9	11[00]	21.5	"	"	"	"	"	"	5380	"	25	1901	3479	4.66
"	10	11[30]	21	.92	330	"	858	"	"	5250	"	22.1	1900	3360	4.5
"	11	12[00]	21.5	.82	365	"	920	7.8	"	5380	1950	23.1	1925	3447	4.58
	12														
	13														

Sheet IIII

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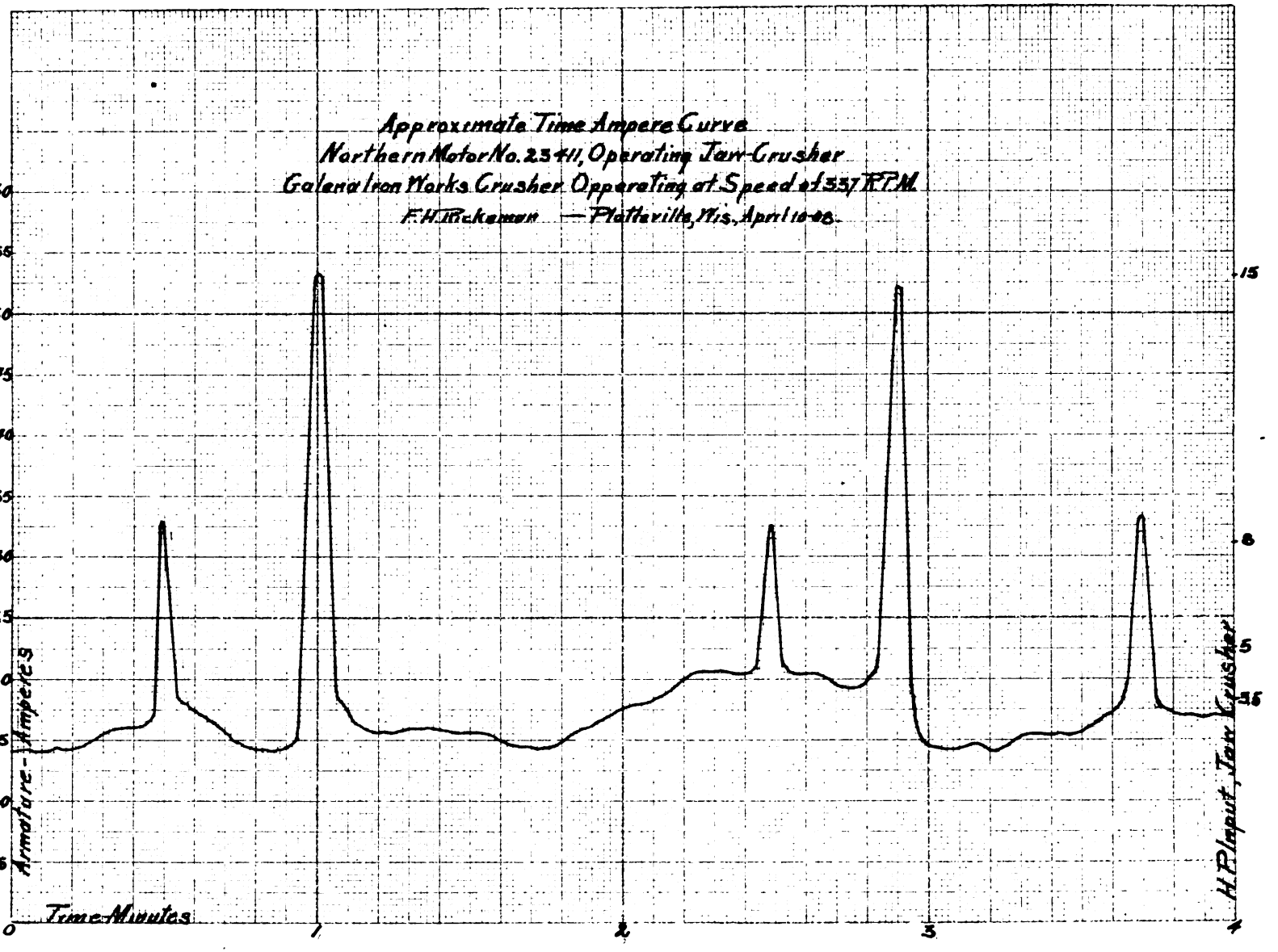
Curve-Sheet II



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jaws. Probably more water fed in with the rock would have modified the excessive loads occasioned by clogging by fine material. All peaks could be modified very materially by putting on heavier flywheels on the shaft of the crusher. This crusher and others in the district have one or two flywheels on their shafts. The speeds cannot be increased for the reason already stated, but the flywheels can be made larger and heavier, and undoubtedly many of the peaks indicated on the curve could be overcome by such alterations. These crushers are installed on foundations made of timbers which elevate the crusher eight or ten feet above the floor in order to provide a fall for the crushed rock. Many of the timbers in the different mines which form such foundations are already very unstable and these conditions result very likely in a large measure from the uneven loads on the crushers. These resulting periodic belt strains also have much to do in causing excessive line shaft friction, as they soon result in vibrating the bearings out of alignment.

On the left margin of the curve sheet the armature amperes are plotted and equal increments of distance represent regular additions of armature current. On the right margin the horse power input is noted to correspond with the armature ampere input. The horse power input does not vary

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regularly however with the increments of distance, because some of the losses in the motor change as the square of the current. This has been mentioned here because a better appearing curve could have been constructed if the horse power input had been plotted in equal increments as ordinates but by adapting this method the same curve has been made to represent both armature ampere input to the motor and the horse power input to the machine under test. Some of the other curves for the test described in this paper have been similarly constructed. The plotted curve mentioned refers to the motor and crusher input when the latter was operating at a speed of three hundred thirty-seven r.p.m. Its normal speed was three hundred thirty r.p.m., but when the motor was used for the test one of the contact points on its starting box had become out of order and it was not put into good order until the test had been about finished.

A Northern motor #23411 was used for operating the crusher for this test, and it was belted directly to the pulley on the crusher. The test was run on the morning of April 10, 1908.

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TEST OF THE NO. I ROLL CRUSHER

Directly under the trough leading to the jaw crushers are located rolls for crushing the broken material into smaller pieces. Usually there are a number of other rolls which again crush the rock into yet finer particles. The crusher rolls which receive the material from the jaw crusher are designated as No. I rolls; they do not differ in design from the rolls which handle the material from them. Sometimes the two rolls which do the crushing are driven in unison by two large star gears, but very often the one roll is driven and the other revolves, owing to the friction from the rock passing down between them.

Sheet No. IX contains a tabulation of the readings and determinations of the power input for the test of this roll, and at the left of the tabulation is noted the running conditions of the crusher. Curve sheet No. III contains a curve plotted from the determinations on sheet No. IX. This curve has been plotted with armature amperes and crusher horse power inputs as ordinates, and time in seconds as abscissas. It will be seen that the average horse power input is comparatively small, it being 1.94 horse power and that there are a large number of peak loads, the maximum of

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No. 1 Roll Crusher

	Reading No.	Volts	Armature Amperes	Field Amperes	Speed of Rolls, R.P.M.	Normal Working Speed, Rolls, R.P.M.	Speed of Motor Pulley, R.P.M.	Armature Amperes, Empty Motor	Total Watts Input	Watts, Core Loss + Friction	Watts C²R Loss	Total Watts Output	H.P. Output of Motor	H.P. Input to Crusher	A.M. Time of Reading
Empty Crusher, Ave. Read'g.	1	245	8.8	.85	32	32	800	8.5	2155	2080	388	71		.095	7¹⁵
" " , Max. Read'g.	2	"	12.8	"	"	"	"	"	3145	"	805	1057	"	1.41	7²⁰
Loaded " , Ave. Read'g.	3	"	14.9	"	"	"	"	"	3650	"	111	1539		2.07	7⁵⁰
" " , Max. Read'g.	4	"	21.5	"	"	"	"	"	5270	"	23	3167		4.25	8⁰⁰
" " , Ave. Read'g.	5	"	14	"	"	"	"	"	3440	"	98	1350		1.81	8⁰⁵
Loaded Crusher, Max. " Once in Two Minutes for Two Seconds	6	"	21.5	"	"	"	"	"	5270	"	23	3167		4.25	8¹⁰
Loaded Crusher, Max. Read'g Once in Five Minutes for Two Seconds	7	"	26.8	"	"	"	"	"	6580	"	36	4464		5.92	8¹⁵
Loaded Crusher, Ave Read'g	8	"	16.2	.71	36	"	885	8.4	3960	2060	13	1887		2.38	9⁰⁰
Loaded Crusher, Max. Read'g Once in Two Minutes for Two Seconds	9	"	23.5	"	"	"	"	"	5760	"	273	3672		4.92	9⁰⁵
Loaded Crusher, Max. Read'g Once in Five Minutes for Two Seconds	10	"	30	"	"	"	"	"	7350	"	45	5245		7.02	9¹⁰
Loaded Crusher, Ave. Read'g.	11	"	14	1.6	24	"	610	8.8	3430	2155	98	1265		1.7	10⁰⁰
Loaded Crusher, Max. Read'g Once in Two Minutes for Two Seconds	12	"	21.5	"	"	"	"	"	5270	"	23	3092		4.13	10⁰⁵
Loaded Crusher, Max. Read'g Once in Five Minutes for Two Seconds	13	"	26.7	"	"	"	"	"	6530	"	35	4344		5.8	10¹⁰
Loaded Crusher, Ave. Read'g.	14	"	17.5	.68	38	"	965	8.5	4270	2080	159	2194		2.93	11⁰⁰
Loaded Crusher, Ave Read'g	15	"	14.5	.85	32	"	800	"	3660	"	21	1449		1.94	12⁰⁰

Sheet IX

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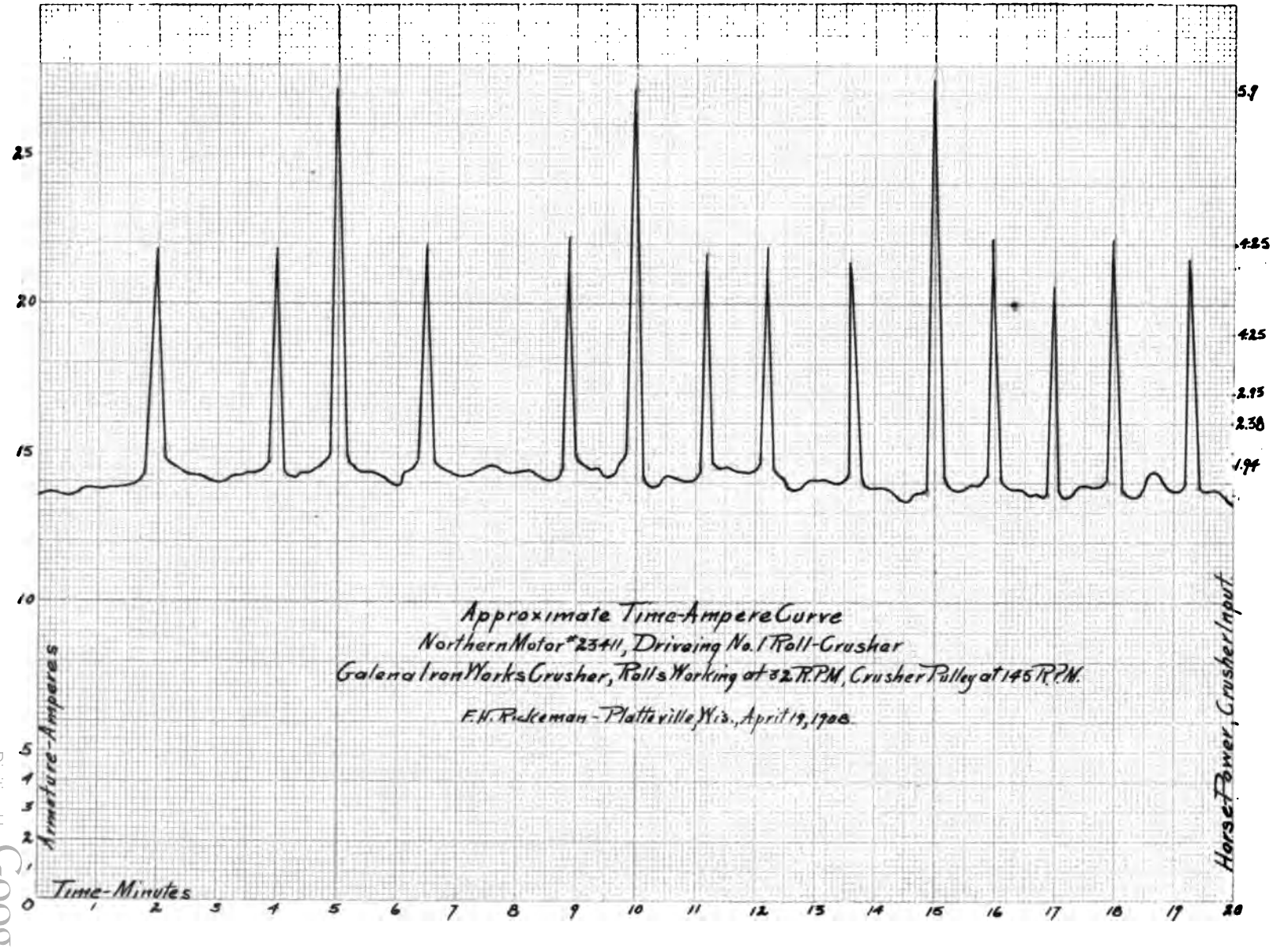
Curve-Sheet III



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which equal 5.9 horse power. These rolls move very slowly and such peakloads are inherent with slow speed machines when handling such irregular material, as uneven broken rock. All crushers of this type in the district are similar in design to the one at the Empire, and the heaviest moving parts are the large gear wheels driven from the pinion on the shaft with the pulley. The gears run very slowly and they impart practically no flywheel effects to the driven rolls. The driven pulleys operating these crushers revolve much faster than the gear wheels, but they are much lighter. The pulleys should be designed for flywheel capacity and a much more uniform power input would be required to operate the crushers. A similar curve plotted under similar conditions of operation, but with the suggested change in the design, would be much more regular, and the peak shown on curve sheet No. III would be greatly modified.

For operating the crushers during this test the motor was placed in position on the floor of the mill and a belt was run over the pulleys of motor and crusher, but an idler-pulley was necessary as the pulley on the rolls extended several feet below the floor. When determining the power input to the crusher the motor losses and the friction losses occasioned by the idler were deducted from the elec-

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trical input to the motor. The curve was drawn from the readings of volts and amperes taken on the portable instruments, and similar to the curve traced upon the chart of the recording ammeter. Motor # 23411 made by the Northern Electrical Manufacturing Company was used for operating the crusher. The test was made on the morning of April 19, 1908.

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TEST OF CHAT ROLL CRUSHER

This crusher resembles No. I crusher in design, but it differs from it by not having the star gears mentioned in the description of No. I crusher. One roll of the chat crusher rotated the other by friction.

Sheet No. X gives the data of the readings and the determinations for the input to this crusher. At the left of the sheet are shown the conditions of operation. This crusher handles much finer material than do the No. I rolls and the same is fed in automatically. In addition to this feed, the mill men feed into it some of the material separated by the jigs and the readings were taken under both conditions. Two curves are platted on curve sheet No. IV from the data given on the sheet above mentioned. The curve drawn in red represents the rolls at a speed above the normal speed of rotation, and the curve drawn in black represents the rolls working at the normal speed. These curves resemble the curve for the No. I roll crusher and the discussion of No. I roll crusher applies to the chat roll crusher. The same motor was used for the test as for the test of No. I crusher, and the test was made on Wednesday morning, April 8, 1908.

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Chat Roll-Crusher

	Reading Number	Time	Volts	Armature Amperes	Field Amperes	Roll R.P.M.	Crusher Pulley R.P.M.	Motor Pulley R.P.M.	Armature Amperes, Empty Motor	Total Watts Input	Watts, Core Losses & Friction	Watts C²R Losses	Watts Motor Output		H.P. Crusher Input
Regular Feed, Ave. Read'g.	1	7¹⁵	250	10.5	1.4	27	130	720	7.8	2625	1950	5.8	669		.897
" " , Max. " .	2	7³⁰	"	14.0	"	"	"	"	"	3510	"	9.8	1550		2.08
Regular Feed and Shoveling in Chat by Hand Ave. Read'g.	3	8⁰⁰	"	11.5	"	"	"	"	"	2880	"	6.6	925		1.24
" " " "	4	9⁰⁰	"	11.5	"	"	"	"	"	"	"	"	"		"
Regular Feed + Shoveling in Chat, Maximum Read'g.	5	9²⁰	"	18.3	1.15	30	145	805	8.0	4580	2000	16.70	2563		3.44
Regular Feed, Ave. Read'g.	6	9³⁰	"	13	1.15	30	146	805	8.0	3252	2000	8.48	1243		1.67
Same as Number 4	7	10⁰⁰	"	13.6	1.10	32	155	860	8.0	3410	2000	9.25	1401		1.88
Regular Feed, Max. Read'g.	8	11⁰⁰	"	15.2	1.15	30	145	805	8.0	3770	2000	11.5	1770		2.38
Same as Number 5	9	11¹⁰	"	19.5	1.1	32	155	860	8.0	4870	2000	19.2	2851		3.82
" " " 4+7	10	11²⁰	"	12.5	1.4	27	130	720	7.8	3130	1950	7.8	1172		1.57
" " " 5+7	11	11³⁰	"	18.3	"	"	"	"	"	4580	"	16.8	2613		3.5
" " " 1+6	12	12⁰⁰	"	12.	"	"	"	"	"	3000	"	7.2	1045		1.39
" " " 2+8	13	12¹⁰	"	14.5	"	"	"	"	"	3680	"	10.6	1670		2.24

Sheet X

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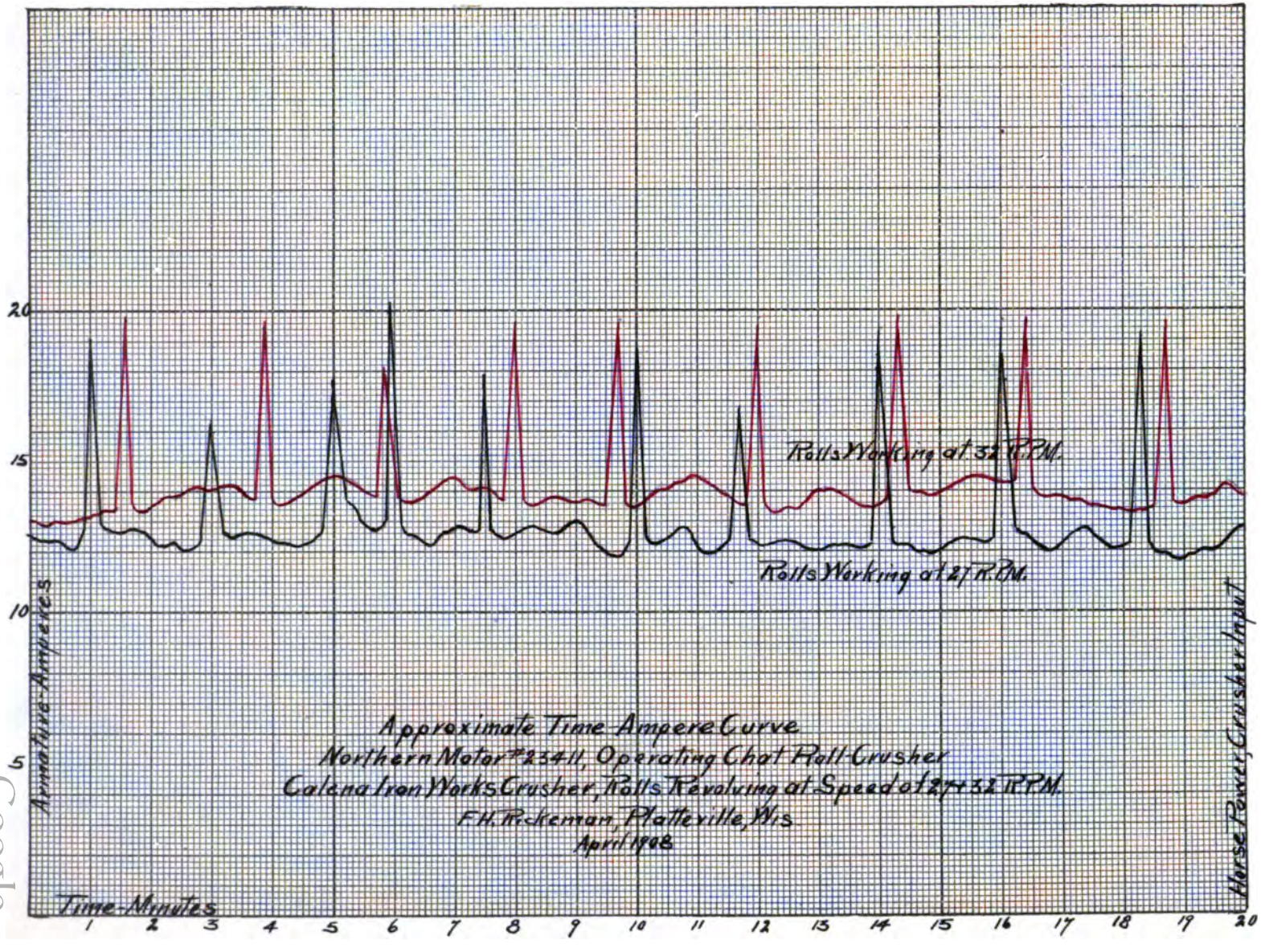
Curve Sheet II


Rolls Working at 32 R.P.M.
Rolls Working at 27 R.P.M.
Approximate Time Ampere Curve
Northern Motor #2341, Operating Chat Roll Crusher
Calena Iron Works Crusher, Rolls Revolving at Speed of 27 & 32 R.P.M.
F.H. Rickeman, Platteville, Wis.
April 1908
Time-Minutes
Armature-Amperes
Horse Power Crusher Input
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
5 10 15 20

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When the tests on both crushers were made approximately ninety tons of rock were being milled in the nine hour shift and the percentage of all ore contents averaged 16.5 per cent.

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TEST OF A DOUBLE BELT ELEVATOR

The test on this belt conveyor was made on Saturday morning, April 11, 1908, and the mill run out ninety-eight tons of rock which averaged 14.3 per cent of ore contents during the nine hours shift. The Empire mill operates five elevators and this was the only double one.

Sheet No. XI gives the readings of volts and amperes and the determinations of power input as well as the speeds of operation and the carrying bucket capacity of the belt. The carrying capacity was taken as one-half of the cubical contents of the buckets, because they never appeared to be carrying amounts of water and crushed rock varying greatly either way from this amount. Several curves are shown on curve sheet No. V and each is for a different speed of operation in feet per minute. The curve in red represents the elevator operating at the normal speed. All these curves show a number of peakloads, the cause for which could not be ascertained. They might have been caused by irregularities in the pulleys over which the belts ran, or they might have occurred owing to irregular feeding from the other apparatus in the mill. These conveyors have little momentum and flywheel capacity cannot easily be applied. The power

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Double Belt Conveyor Elevator

Reading	Time	Volts	Armature Amperes	Field Amperes	Speed Elevator Pulley R.P.M. Normal	Speed Elevator Belt Feet Per Minute	Speed Motor Pulley R.P.M.	Total Number Buckets	¼ Total Cubical Contents of Buckets	Armature Amperes Empty Motor	Watts Input - Loaded Motor	Watts Core Loss Friction	Watts C²R Loss	Watt Output	Horsepower Output Carrying Capacity	Horsepower Input per Cu. Ft. Carrying Capacity of Buckets	Horsepower Input per Cu. Ft. Carrying Capacity per 100 Ft. per Min.	Ave. or Maximum Reading	
1	7¹⁵	250	19.3	.95	205	331	322	870	60	691	7.5	4850	1875	18.6	2936	3.93	.569	.172	Ave
2	8⁰⁰	"	19.3	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
3	8¹⁰	"	19.4	.75	238	385	"	1030	"	"	7.8	4850	1955	18.8	2876	3.86	.558	.146	"
4	8²⁰	245	22.5	"	288	"	"	"	"	"	"	5610	1875	25.3	3630	4.87	.705	.184	Max.	Once per Min.
5	8³⁰	250	17.2		286	241	"	660	"	"	7.5	4210	1875	14.8	2315	3.78	.544	.226	Ave	
6	9⁰⁰	"	24.2	.94	286	460	"	1340	"	"	8.0	6050	2000	29.4	4020	5.4	.752	.168	"	
7	10⁰⁰	"	31.8	"	"	"	"	"	"	"	"	7950	"	50.6	5900	7.9	1.14	.252	Max	Once per Min.
8	11⁰⁰	"	19.2	.94	205	331	"	870	"	"	7.5	4800	1875	18.5	2906	3.9	.565	.17	Ave	
9	11⁴⁰	"	"	.95	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
10	11⁵⁰	"	"	.95	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
11	12⁰⁰	"	18	.98	200	322	"	870	"	"	"	4500	"	16.2	"	3.6	.52	.162	"	
12	12¹⁰		21	"	"	"	"	"	"	"	"	5250	"	22.1	3555	4.5	.65	.201	Max	Once per Min.
13	12¹⁵		18	"	"	"	"	"	"	"	"	4500	"	16.2	2609	3.6	.52	.162	Ave	

Sheet XI

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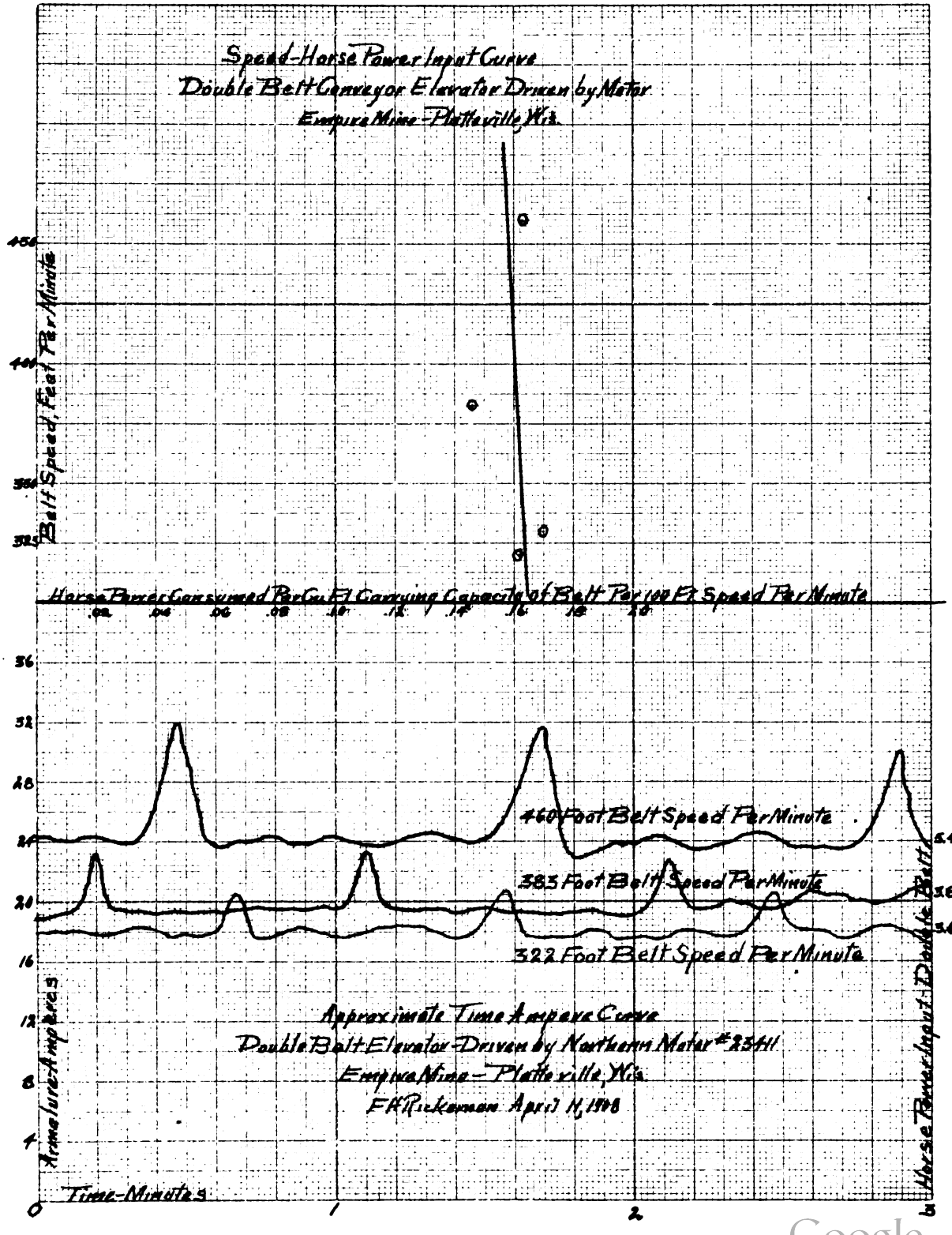

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Curve-Sheet V

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input required for their operation is small and very little economy or advantage could be gained by making them operate with a more regular power input. The power required for operating these conveyors varies in a certain degree with their carrying capacity and speed, and the upper straight line curve is plotted from four readings at different speeds. The revolving buckets occasion considerable air friction, and at high speed this circumstance would be an important factor in effecting the operation of these elevators. The speeds at which such conveyors are run represent approximately the maximum, since at higher speed they splash considerably. The customary belt elevator installed in the mines does not consume much power and probably two and one-half horse power would be all the power required to operate one. When determining the total horse power input to the complete mill equipment at the Empire, the top curve was used for such computations, and results were obtained which appeared to the writer to be satisfactory. It is not intended that any such method should be used when figuring on a mill equipment of a power input, because an approximation could be made more easily. Such elevators are not well located for individual motor drive, and for operation by separate motor drive the only practical method to adopt would be to group them so as to operate all of them by one motor. Sometimes the tail-

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ings elevator is isolated and of considerable height and with such a problem to solve an individual motor drive might be well applied.

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TEST OF MATHEY JIGS

The majority of jigs in the district have recently been installed by the Galena Iron Works, and may be designated as the Mathey type, since they have been introduced by Mr. Mathey, president of the above company. These jigs make a very good ore-separation by the gravity process. They are built up customarily with two inch by four inch timbers and along the center of one-half of the division of the top is run a steel shaft supported by bearings on either end and at the cell-divisions. From the shaft are operated a number of plungers made in the shape of square areas of one inch boards. The plungers are given an up and down motion by eccentric connections to the shaft. Owing to the light structure of the jigs the shaft soon gets out of alignment and there results a large friction loss. Sheet No. XIII and curve sheet No. VII give readings and determinations of power input and show a curve for the sander-jig operating unloaded or without any water in the cells. It will be seen from these sheets that the friction losses amount to more than fifty per cent of the power input required for operating the jig under working conditions. Such power loss is constant and continues many hours per day. It would therefore pay a

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Sheet III

Rougher Jig, Seven Plungers

Number of Reading	Time	Volts	Armature Amperes	Field Amperes	Plunger Strokes Per Minute	Normal Number Strokes Per Min.	Number of Plungers Tested	□ Inches Area of Each Plunger	□ Inches Total Plunger Area	Inches Ave. Length of Strokes	Armature Amperes Empty Motor	Total Watts Input	Watts Core Loss & Friction	Watts C^2R Loss	Total Watts Output	Total H.P. Input to Four Plungers	H.P. Input per □ In. Plunger Area per ½ Inch Stroke	H.P. Input per □ Ft. Plunger Area per ½ Inch Stroke per 100 Strokes per Minute
1	7:30	255	13.2	.75	207	185	4	1141	4484	11/16	2.05	3876	512	86	3278	4.4	1.1	.0128	.0061
2	8:30	240	14.7	.85	196	"	"	"	"	"	2.1	3550	502	79	2949	3.96	.99	.0112	.0057
3	9:30	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
4	10:30	"	16.2	.72	206	"	"	"	"	"	2.25	3810	540	92	3258	4.38	1.09	.0127	.0061
5	11:20	242	19.7	.61	230	"	"	"	"	"	2.4	4758	575	145	4023	5.4	1.35	.0158	.0066
6	11:30	250	15.2	.72	206	"	"	"	"	"	2.05	3850	506	86	3258	4.36	1.09	.0127	.0061
7	11:40	242	14.7	.71	196	"	"	"	"	"	2.1	3550	504	79	2967	3.99	1.00	.0112	.0057
8	11:50	242	12.8	1.0	185	"	"	"	"	"	2.1	3080	480	60	2540	3.4	.85	.0099	.0055
9	12:00	"	11.2	1.25	175	"	"	"	"	"	"	2700	484	47	2170	2.92	.73	.0085	.0048
10	12:15	"	16.7	.8	200	"	"	"	"	"	2.1	3850	504	90	3256	4.2	1.05	.0123	.0061

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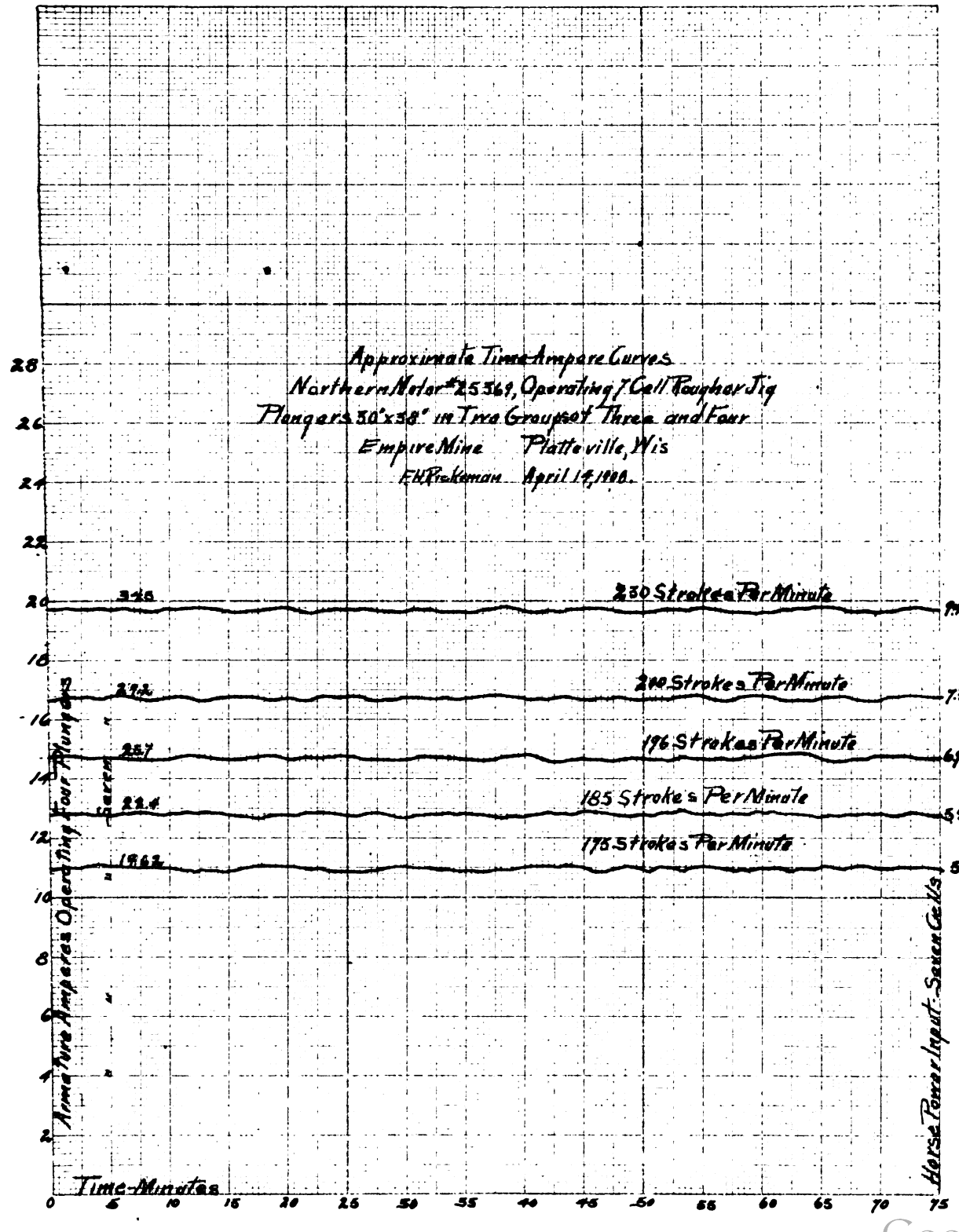

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Curve Sheet VI

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Sheet XIII

Seven Plunger Sander Jig

Reading No.	Time	Volts	Armature Amperes	Field Amperes	Plunger Strokes P.M.	Normal "	No. of Plungers	□in. Area of Each Plunger	Speed Motor Pulley R.P.M.	Inches, Ave. Length of Strokes	Armature Amperes, Empty Mot	Total Watts Input	Watts Core Losses + Friction	Watts Output	Total Watts Output	H.P. Input Four Plungers	H.P. Input Each Plunger	H.P. Input per □ Fl. of Plunger	H.P. Input per □ Fl. of Plunger Area per Stroke per Sq. In.
1	8⁰⁰	218	15	.95	215	200	4	1121	780	55/64	2.45	2070	584	53.3	1508	2.01	502	.0645	.00747
2	9⁰⁰	"	15	"	"	"	"	"	"	"	"	3270	"	853	2655	3.55	.887	.1155	.0182	.0062
3	10⁰⁰	"	15	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	.0062
4	11⁰⁰	"	15	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	.0065
5	11³⁰	"	17.2	.85	225	"	"	"	748	"	"	3755	"	1080	3113	4.16	1.04	.1375	.0158	.0071
6	11³⁰	"	14.8	.95	215	"	"	"	780	"	2.5	3755	540	80.8	2604	3.48	.87	.1138	.015	.0061
7	11³⁰	"	14	1.15	200	"	"	"	725	"	2.4	3225	518	72.4	2445	3.31	.852	.1095	.0125	.0062
8	11⁴⁰	"	13.1	1.30	190	"	"	"	690	"	"	2860	"	62.9	2279	3.05	.762	.098	.0112	.0062
9	12⁰⁰	"	15	.95	215	"	"	"	780	"	2.45	3270	534	853	2653	3.55	.887	.1155	.0182	.0063
10	12¹⁵	"	15	.95	215	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
11																				

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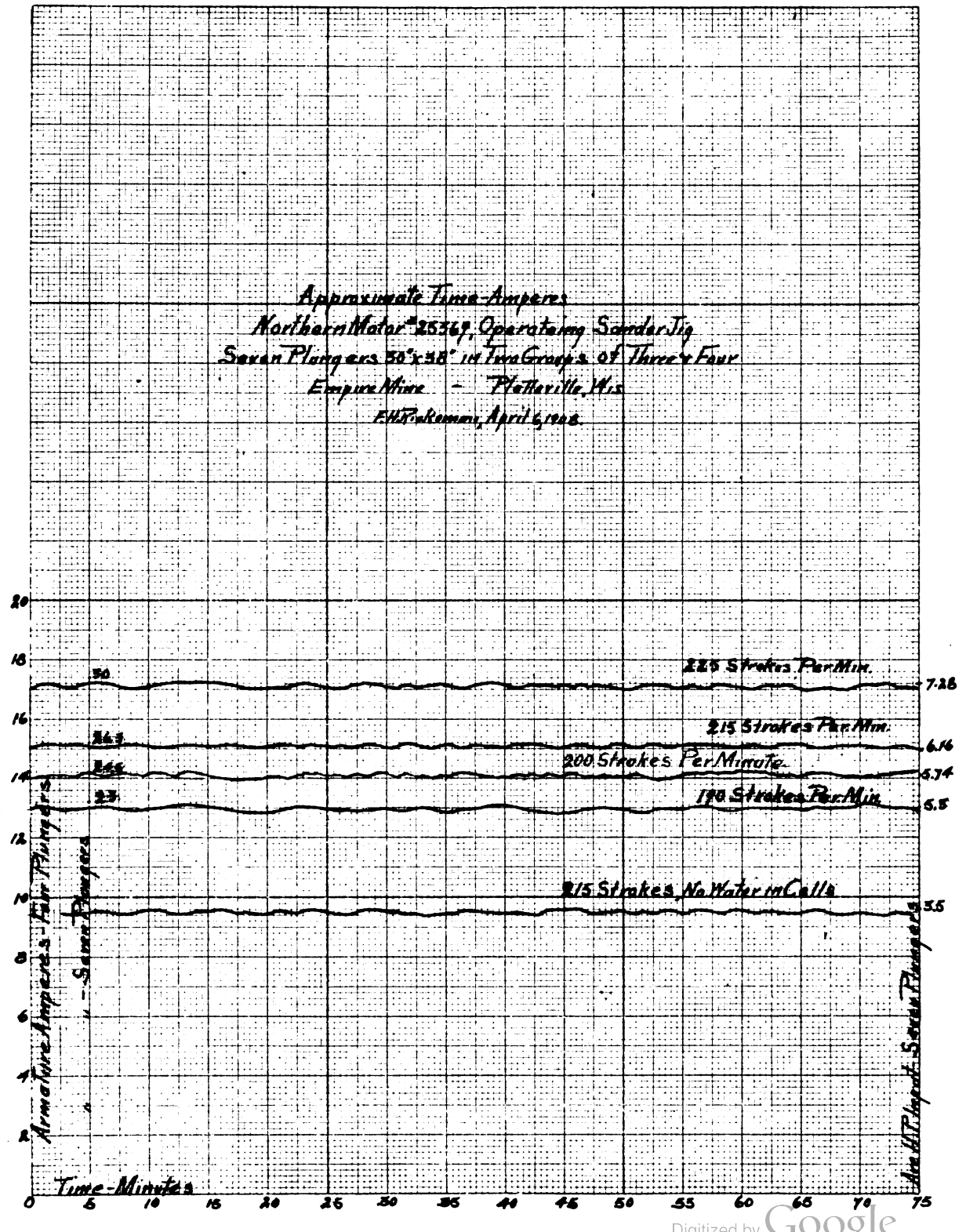

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Curve Sheet VII

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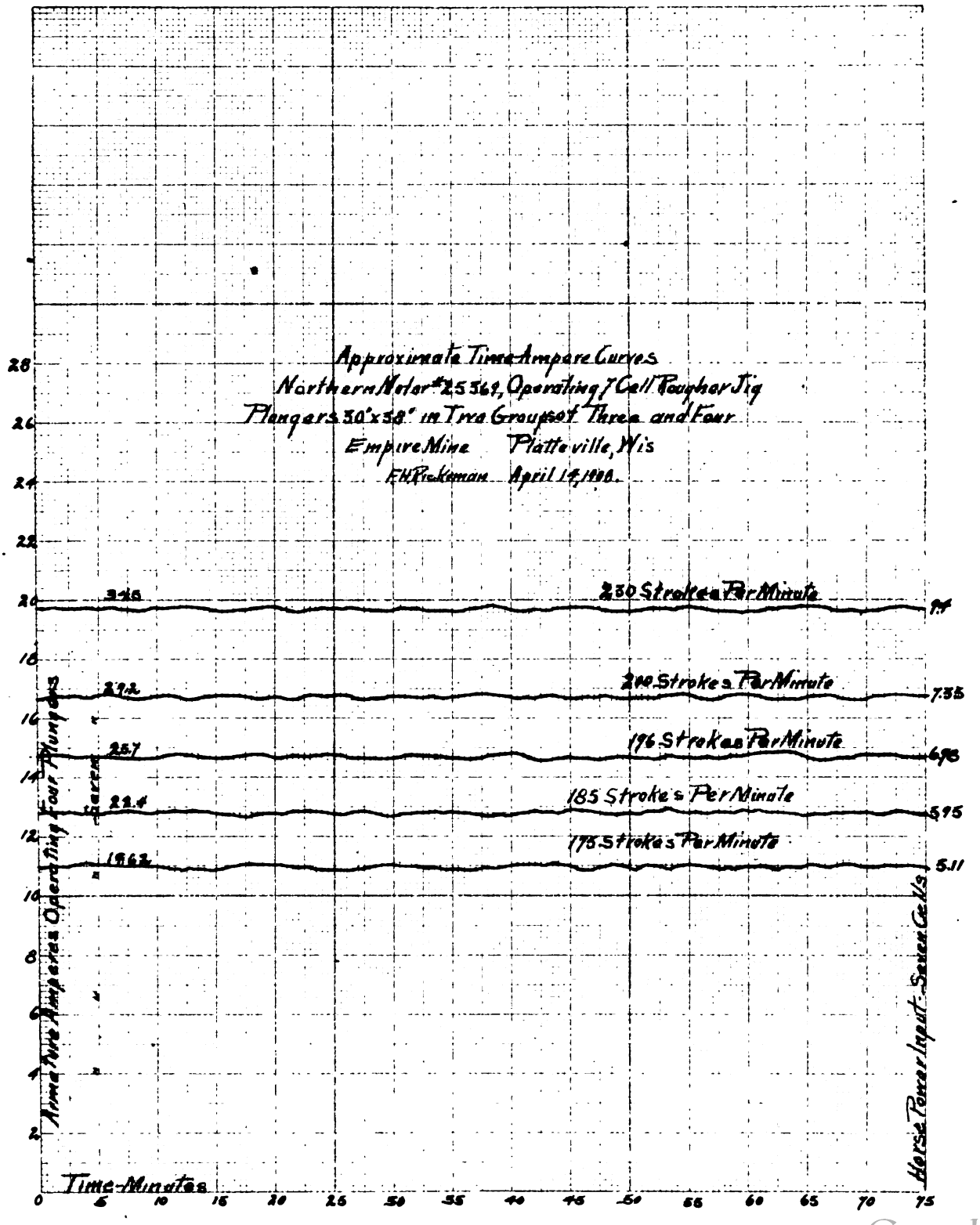

Curve Sheet VI

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Seven Plunger Sander Jig

Reading No.	Time	Volts	Armature Amperes	Field Amperes	Plunger Strokes P.M. Normal "	No. of Plungers	□in. Area of Each Plunger	Speed Motor Pulley R.P.M.	Inches, Ave. Length of Strokes	Armature Amperes, Empty Motor	Total Watts Input	Watts Core Losses + Friction	Watts C²R Loss	Total Watts Output	H.P. Input Four Plungers	H.P. Input Each Plunger	H.P. Input per □ Fl. of Plunger Area	H.P. Input per □ Fl. of Plunger per ¼" Stroke per Min.	H.P. Input per □ Ft. Plunger Area per ¼" Stroke per 100 R.P.M.
1	8^00	218	15	.95	215	200	4	1121	780	55/64	2.45	2070	584	53.3	1503	2.81	.502	.0645	.00757	
2	9^00	"	15	"	"	"	"	"	"	"	"	3270	"	852	2653	3.55	.887	.1155	.0152	.0062
3	10^00	"	15	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	.0062
4	11^00	"	15	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	.0065
5	11^30	"	17.2	.85	225	"	"	"	748	"	"	3755	"	1080	3113	4.16	1.04	.1375	.0158	.0071
6	11^30	"	14.8	.95	215	"	"	"	780	"	2.5	3755	540	80.8	2604	3.46	.87	.1138	.015	.0061
7	11^45	"	14	1.15	200	"	"	"	725	"	2.4	3225	518	72.4	2465	3.31	.852	.1095	.0125	.0062
8	11^52	"	13.1	1.30	190	"	"	"	690	"	"	2860	"	62.9	2277	3.05	.762	.098	.0112	.0062
9	12^00	"	15	.95	215	"	"	"	780	"	2.45	3270	534	852	2653	3.55	.887	.1155	.0152	.0063
10	12.15	"	15	.95	215	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
11																				

Sheet XIII

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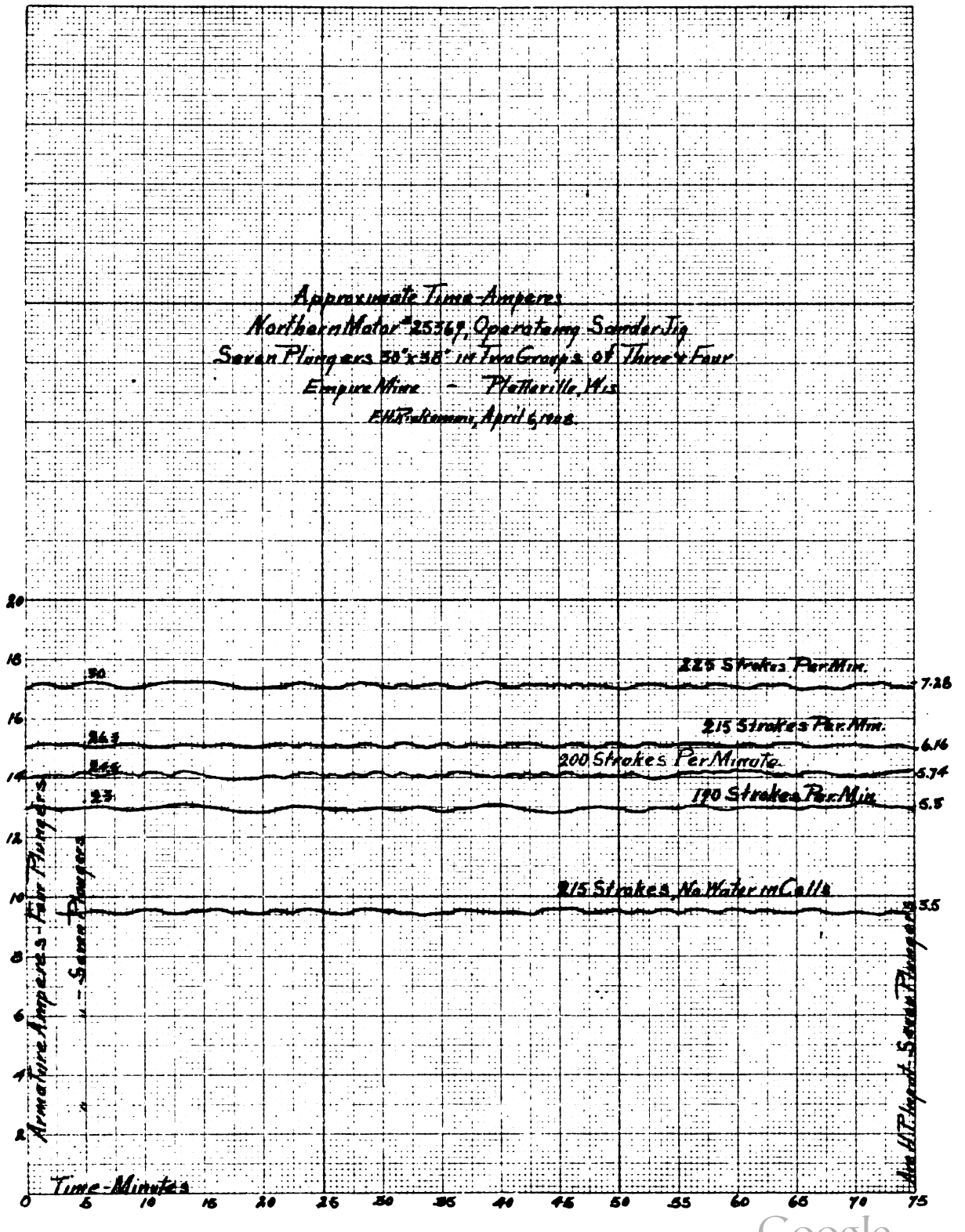

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Curve Sheet VII

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Sheet III

Five Plunger Sludge Jig

Reading No.	Time	Volts	Armature Amperes	Field Amperes	Plunger Speed, S.P.M. Normal "	Motor Speed, Pulley R.P.M. "	No. of Plungers	□ Inches, Area Each Plunger	Inches, Ave. Length of Strokes	Armature Amperes, Empty Note	Total Watts Input	Watts Core Losses	Watts C & R. Losses	Total Watts Motor Output	H.P. Input to Plungers	H.P. Input Per Plunger.	H.P. Input per □ Ft. Plunger Area.	H.P. Input per □ Ft. Plunger Area. per 1/2 Inch Stroke per 100 S.P.M.
1	7²⁰	240	8.8	1.0	225	240	930	5	630	9/16	2.52	2110	604.8	247	1478.5	1.98	.396	.09	.01	.0044 *
2	7⁴⁰	250	11.2	1.0	"	"	930	"	"	"	2.5	2800	625	462	2129	2.85	.57	.13	.014	.0064
3	8⁰⁰	"	"	1.0	"	"	930	"	"	"	"	"	"	"	"	"	.57	.13	"	.0064
4	9⁰⁰	"	10.5	1.1	215	"	890	"	"	"	"	2625	"	486	1952.9	2.63	.526	.121	.0134	.0062
5	9¹⁰	"	12.2	.8	240	"	1003	"	"	"	2.6	3050	650	548	2345	3.13	.626	.141	.0156	.0065
6	9²⁰	"	13.2	.7	260	"	1080	"	"	"	"	3300	"	642	2585	3.46	.692	.159	.0176	.0067
7	10⁰⁰	"	12.2	.8	240	"	1003	"	"	"	"	3050	"	548	2345	3.13	.626	.141	.0156	.0065
8	11⁰⁰	"	12.2	.8	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
9	11³⁰	"	"	.8	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
10	12⁰⁰	"	"	.8	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"

* Total Friction Load, No Water on Plungers

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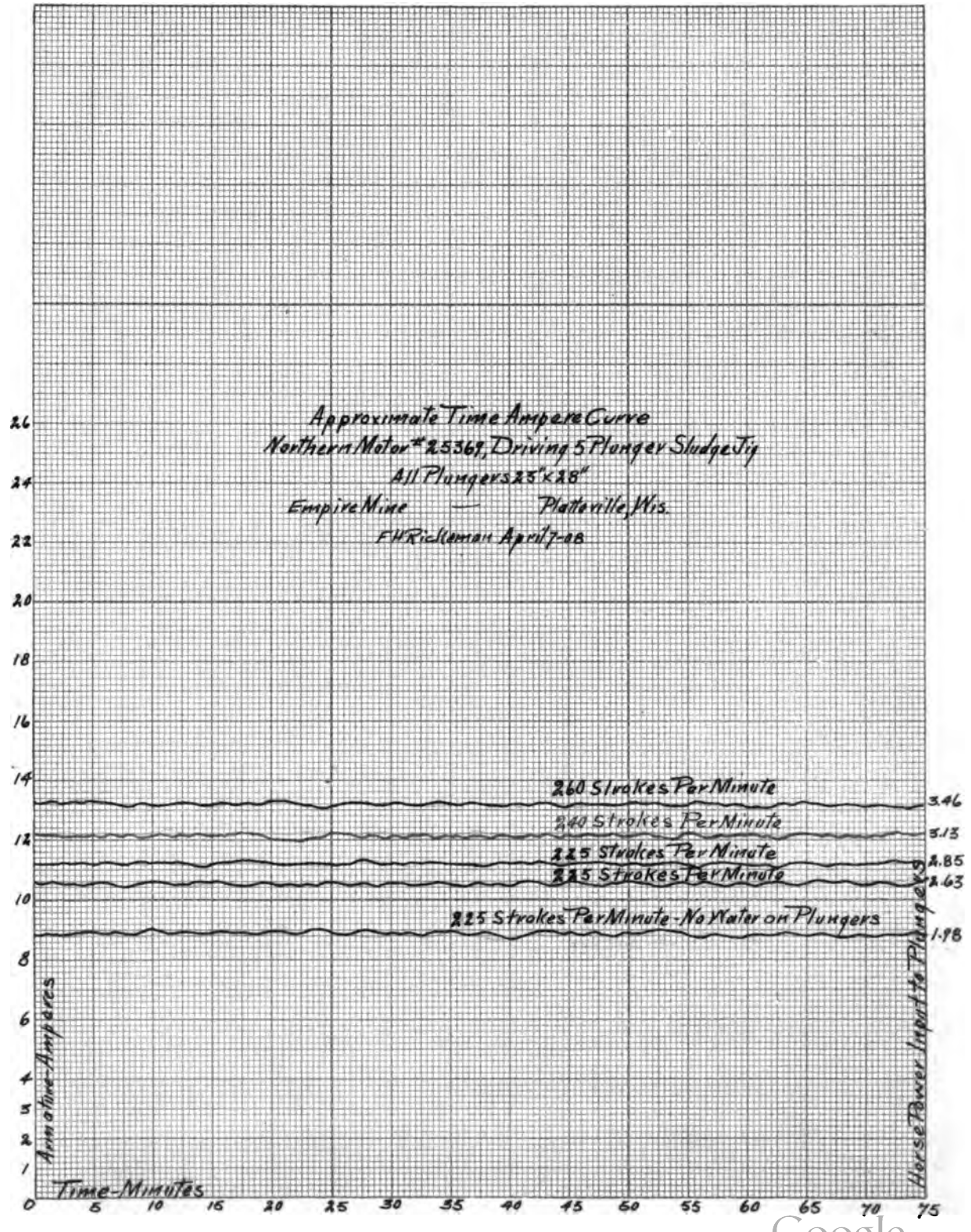
Approximate Time Ampere Curve
Northern Motor # 2536, Driving 5 Plunger Sludge Jig
All Plungers 2.5" x 2.8"
Empire Mine — Platteville, Wis.
F.W. Richtemeier April 7-08
260 Strokes Per Minute
240 Strokes Per Minute
225 Strokes Per Minute
225 Strokes Per Minute
225 Strokes Per Minute - No Water on Plungers
3.46
3.13
2.85
2.63
1.98
Armature-Amperes
Horse Power Input to Plungers
Time-Minutes
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
1 2 3 4 6 8 10 12 14 16 18 20 22 24 26

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Curve Sheet VIII

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mine management well to keep such shafts and moving parts in the best of order so as to keep friction losses at a minimum.

Curve sheet No. VI and sheet No. XII contain data and curves relative to an input test on a seven plunger sander-jig. Only four plungers were operated from one belt and consequently only four were tested, but the power input to the complete jig was calculated from the results obtained from the test of the four plungers. On curve sheet No. VI the red curve refers to normal working conditions of the jig and reading No. 8 on sheet No. XII refers to similar conditions of operations of operation for this jig. All curves for the various speeds are practically uniform, indicating that the required power input is very constant. On curve sheet No. VII and sheet No. XIII, the curve in red refers to normal working conditions of the sander jig, and reading No. 7 refers to the data for such condition of operation. Likewise curve sheet No. VIII and sheet No. XIV show the curves of armature ampere input to the motor operating the five cell sludge jig, and the data and determinations of the power input. Likewise the curve in red is drawn with reference to data obtained for the normal working conditions of operation, and readings No. 8, 9, and 10 refer to like conditions of operation.

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All the curves show that the loads on the jigs are uniform. One of the curves on curve sheet No. VIII also indicates that the friction load of the sludge jig is more than half of the full load.

For each of the jigs the total horse power input per plunger is calculated as well as the input per square foot of plunger. The calculations are also carried further and the power input per unit of area of plunger, per unit length of stroke, and per unit of speed, can be seen tabulated. These calculations were made for the purpose of determining if there were constants which might be used for deciding the power input required for operating jigs of this construction. My figures indicate that there are, but the curves may furnish sufficient information for determining such data, since they are drawn for various speeds of operation and the sizes of plungers used on the three jigs are nearly standard throughout the district.

When the test were made, approximately one hundred tons of rock were being jigged per nine hour shift. The amount of rock in the jigs will however affect the power input necessary for operating the jig a very little, indeed, if at all. The friction load being as already stated more than one-half of the entire load, the balance of the load will depend principally upon the amount of water displaced by the

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plungers and likewise upon the friction occasioned by the water surrounding the plungers.

Because the mill was in regular operation when these tests were conducted, considerable delay and annoyance would have been occasioned if it had been attempted to change the length of stroke of the plungers, but it is very probable that alterations of the length of stroke of these plungers would change the power input. The data in the tabulation includes some results obtained by using the length of stroke as a factor effecting the power input.

There is no doubt in the minds of such mine superintendents as have thought intelligently about the subject of speed variation of the jig plungers that much economy would result thereby. Different grades of rock and varying percentages of ore and different sizes of crushings all require different speeds of plunger operation in order to produce the most efficient results at separation. In the Wisconsin district no attempt has been made to operate the jigs in this manner and it would be impossible to do so with the present installations as they are all driven from one line shaft and a speed variation of one machine would result in a like variation in the speeds of all the other apparatus. If each jig were driven by a separate variable speed motor such conditions could be maintained and individual motor

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drive would undoubtedly be very satisfactory for jig operation.

All of the above tests upon the jigs were made with a Northern motor #25369 on April 6, 7, and 14, 1908. The idler pulley which was used when testing the crushers was used when making tests on the jigs, and the friction losses occasioned by the idler pulley were deducted from the motor output for determining the power input to the jigs.

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TEST OF THE EIGHT INCH CORNISH CROSS HEAD LIFT PUMPS

There is no other machine about a mine upon which the future of the mine so much depends as upon the pumps for keeping the underground workings drained. Many of the Wisconsin zinc mines are closed down to-day because the pumps which were installed were inadequate to handle the water, or because the pumps were defective in design and material, and because the expense of pumping could not be borne by the company.

The most satisfactory pump which has been used in the lead and zinc mines in Wisconsin is the old-fashioned Cornish lift pump. When such a pump is properly designed and if well installed and well chosen with regard to pumping capacity, it forms a very good pumping equipment. The ordinary workman can easily make the required repairs with simple tools and practically the only attention that they require is repacking. If the water can be kept down below the working barrel by an auxiliary pump or by one of the Cornish pumps when there are two installed, as is customarily done, repacking of the plungers can be accomplished in several hours. The gritty water which is continually being expelled from the underground workings, soon wears out the best packing which can be obtained, and this type of pump requires re-

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packing quite frequently; the packing rings requiring replacement sometimes after a weeks period of operation.

The most serious error when installing this type of pump is in putting in foundations which are not heavy and substantial enough. The main bearings are placed upon heavy timbers in all instances and in one or two installations these timbers are installed upon concrete piers. The foundations of this type have been substantial enough, but in the vast majority of installations the whole foundation structure consists of a timber framework, and when the pumps are of large capacity, the foundation rocks with each plunger stroke, which results in throwing the large bull wheels and pinions out of mesh, occasioning serious difficulties and breakdowns very soon afterward. Probably if substantial foundations were put in with the majority of the installations, they would be the strongest part of the equipment, and the pump parts would break from the shock occasioned by the inertia of the heavy columns of water which must be kept in motion by the plungers. Many of the installations of Cornish pumps were examined by the writer and there seemed to be little engineering method used in designing them. In some cases the area of the discharge pipes was much too small to take the discharge from the column pipe without the water

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having to be lifted a number of feet above the connection of the discharge pipe to the column pipe. In two or three instances, the water is discharged into the discharge pipes ten and twelve feet above the surface of the ground, while the pond for the mill water receives all the discharged water directly from the discharge pipes. These two conditions affect the efficiency of operation of the pumps. The hubs on many of the heavy bull wheels are very much too weak and all out of proportion to the strength put into other parts of the wheel. The same size of plunger rods are often used in pumps of eight and ten inch working barrels as in those of sixteen inch diameter working barrels. Evidently if such rods are heavy enough for the larger pumps they are too heavy for the pumps of the smaller capacity and if they are only substantial enough for the small pumps they must be much too weak for the larger. In one instance a steel pinion shaft operating plunger rods for two sixteen inch diameter working barrels was more than an inch less in diameter than the pinion shaft operating the gear wheels of two ten inch working barrels. Both pumps were operated at like speeds and both installations were put in by the same firm.

Perhaps it is not in all cases an error in engineering

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as the working capital of the mining company may be one of the determining factors, but a good pumping equipment is more of a necessity for the mining corporation with small capital than for the one with the large working capital, since it will financially break a corporation quicker than any of the other adjuncts of a mine installation. A shut-down of the pumping plant not only causes a shut-down of all of the underground workings for the period that the pumps are out of service, but also for that period required to again underwater the mine.

Data sheet No. XV contains the data referring to the readings of motor input when operating a set of two eight inch working barrel Cornish lift pumps at the Empire mine. These pumps are being operated by a belted motor of the Nortern Company's manufacture, and input readings to the installed motor were taken, and the losses of the motor deducted for determining the power input to the pump. The motor was of the compound wound type, and of forty horsepower rated capacity. It was belted to the pinion shaft of the pump and was capable of slight speed variation by field control.

The water discharged by the pumps was determined by discharging them into a tank which was accurately measured for its cubical contents and the time taken to fill it with water was determined by stop-watch readings. The total lift

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Sheet XII

Double Cornish Cross-head 8" Lift Pumps

Reading No.	Time-Seconds Duration of Test	Cu. Feet Water Disc. Per Minute	Total Lift incl. Friction Head	Strokes per Minute	Inches-Length of Strokes	Diam. of Working Bbl.	Cubic Ft. Per Stroke of Piston Per Barrel of Displacement	Per Cent of Slippage	Armature Amperes	Armature Amperes Empty Motor	Volts	Total Watts Input	Watts Core Loss & Friction	Watts C²R Loss	Watts Output Motor	Horse Power Output Motor	Water Horse Power Pump			Pump Efficiency
1	100	46.5	156	20.5	48	8	1.386	182.	93	15.9	233	21699	1578	570	19731	26.45	13.71			51.7
2	105	45.76	"	"	"	"	"	19.5	92.1	"	234	21551	1582	509	19670	26.3	13.48			51.2
3	110	47.1	"	"	"	"	"	17.8	94.	"	"	21925	1572	601	19950	26.8	13.85			51.7
4	100	46.	"	"	"	"	"	18.4	92.8	"	233	21687	1578	539	19776	26.5	13.57			51.2
Average																				51.4

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was determined by measuring the distance from the level of the water in the pump underground to the center of the discharge pipe, and to this height was added the friction head as determined for the column pipes and discharge pipes for the velocity of flow of water through them.

The average efficiency of the pumps was found to be 51.4 per cent and the slippage was found to be 18.5 per cent. The pumps had recently been repacked, which resulted in a slippage which is often exceeded in many of the pumps in use in this district.

This test concludes the series of tests which were made at the Empire mine. Several other tests were made by the writer on other pumps in the district, and the results of such tests will now be stated.

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TEST OF TWO TEN INCH CORNISH LIFT PUMPS

There are now installed at Hazel Green, Wisconsin, at one of the mines two sixteen inch working barrel Cornish pumps which have recently replaced two ten inch working barrel pumps of the same type. The two smaller pumps were tested on August 15, 1908. They were operated by a Northern Electric Company seventy-five horsepower belted motor #25010. The pumps were operating with six foot strokes at a rate of fifteen and one-half strokes per minute. One working barrel was ten inches in diameter, and the other was ten and one-half inches in diameter. The total lift including friction head was one hundred and thirty-one feet.

The discharge water was conducted from the pumps through a line of piping to a creek which was dammed with a weir dam. A number of baffle plates were made of planks and those were placed across the stream so that the water would have no appreciable velocity head at the weir dam. The readings for discharge through the weir were taken with considerable accuracy and a number of them were taken so as to be able to furnish figures for a fair average for the quantity of water discharged.

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The readings indicated that 796.9 gallons per minute of water were being discharged. The piston displacements in gallons per minute represented 1008.7 gallons, and the slippage as determined from these figures was twenty-one per cent. The watt input to the motor was 44,387, and the core and friction and c^2r losses were 8,429.8 watts, leaving a net input of 35,956 watts or 48.2 horsepower to the pumps.

The water horsepower represented by the above mentioned discharge was 26.4 horsepower and these figures represent a pump efficiency of 54.5 per cent which is somewhat in excess of that obtained for the efficiency of the pumps at the Empire mine.

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TEST OF TWO SIXTEEN INCH CORNISH LIFT PUMPS

The ten inch pumps above mentioned were found to be inadequate to handle all the water encountered and they were replaced this spring by two Cornish lift pumps with sixteen inch and fifteen and three-fourths inch working barrels respectively and discharging through eighteen inch column pipe. On May 28, 1909 readings for power input to these pumps were taken. The same seventy-five horsepower motor which formerly operated the ten inch pumps was driving them and the head pumped against had been changed considerable from the head against which the previously installed pumps operated. The total working head including the friction head of the pipes for the velocity of water flowing when tested was 107.5 feet. The plungers were working at the rate of fourteen and three-fourths strokes per minute. The water discharged was determined by weir measurement and amounted to 1159.7 gallons per minute as determined by the average of five different readings. The bucket displacements with a plunger stroke of seventy-two inches amounted to 1812 gallons or 418572.7 cubic inches. A slippage of 652.3 gallons was taking place at this rate of discharge and the same amounted to 36.1 per cent, which is somewhat

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excessive and greater than the percentage of slippage for the other two pumps discussed. The above discharge represents a water horsepower of 29.28 at the head mentioned.

The motor input as determined by readings of volts and amperes from the switch-board instruments which were checked by calibrated portable Weston instruments was 46625.3 watts and the calculated losses of the Northern motor, number 25010, was 6937.9 watts. The above motor input of 62.5 horsepower less its losses of 9.3 horsepower left an output or a pump-input of 53.2 horsepower and the pumps were therefore operating at an efficiency of approximately fifty-five percent.

The average efficiencies of the three Cornish pumps which were tested amounts to 53.6 per cent and neither efficiency varies much from this figure. The three slippage factors, however, vary considerably. The sixteen inch pumps which have been discussed are not new pumps but when they were installed new working barrels and buckets had been supplied, but there is undoubtedly a misfit somewhere in the working barrel or in the valves. The pumps had just recently been repacked when the test was made and the slippage should not have been so excessive.

Very few of the Cornish pumps in the district are motor driven and there is no method at hand for accurately

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checking up these results for determining approximate efficiencies or slippage factors. Unquestionably many of them are operating very uneconomically and their working conditions could in all probability be easily improved if there was at hand conveniences for checking up their operating conditions.

Only two centrifugal pumps have been operated in the district for pumping water from the underground workings. These were unfortunately of a type from which good efficiencies could not be expected. They were of the direct-motor driven vertical turbine type made in such a manner that the five stage impeller pumps could be installed down a sixteen inch drill-hole. The vertical connecting shaft between motor and pumps was approximately one hundred and twenty feet in length and the inner bearings had been removed and others installed which were of a type which allowed the shaft bearings to be water lubricated and not by oil as the manufacturer had intended. Even under such unfavorable conditions an efficiency o f operation of more than sixty per cent was obtained by the writer at a test last fall when the pumps were discharging at a head of about one hundred and thirty-five feet. One of these pumps had been in service for more than two years and had required scarcely any repairs or attention.

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Such a type of pump is however not adapted for sinking purposes unless a drill-hole is sunk within a few feet from where the mine shaft is being put down.

A very satisfactory type of pump is however manufactured which resembles the type discussed. The motor and pump are installed in close proximity with no intervening shaft between the motor and pump shaft and the operating motor is made splash proof. Such a pump would unquestionably give much better economy and satisfaction than the present lift pumps. A discharge connection would necessarily have to be provided which would allow lifting and lowering of the motor and pump during sinking operations.

This will end the discussion on the tests which were conducted in the lead and zinc district by me, and a few words of general discussion related to these tests will follow.

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ELECTRIC POWER FOR THE WISCONSIN LEAD AND ZINC MINING DISTRICT

A company has recently been financed and the engineering is well under way for a power transmission system extending north from Galena as far as Platteville, with branches east and west of such a route to the nearby mines. The writer has visited nearly every mine in the above mentioned limits of the mining district and believes that electric power for this district will result in a great boon to the mining industries. The price of coal delivered at the mines is prohibitive with the price of ore as low as at present, and with the inefficient power plants which the mining companies cannot afford to improve. Many of the mines which are unfortunately located some distance from the railroad must haul their coal over roads which are impassable at times in the spring. A number of mines were closed down a few months ago for this reason. The freight rates for coal north from Galena is ninety cents per ton and some of the mines pay as high as two dollars per ton for hauling coal to their plants.

Some of the mines in the district have already contracted for electric power, and the others will be fortunate

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if they can procure the service when the line is run up the district. The rates which are to be charged for electric service will depend upon the horsepower hour consumption, but it will be sold at such rates as will lessen the cost of operation of the mines considerably. If the charge for electric service equalled the cost of fuel and labor for steam power drive there would be a large saving occasioned by the use of motor drive, since the boiler troubles and maintenance would be done away with. The boiler water throughout the district is very bad and its corrosive action and the sediments which it deposits in the boiler shells cause many shut-downs of the power plants.

The larger number of mines have the ordinary simple slide-valve engines installed, and their economy is very low. Likewise steam-driven air compressors are employed in nearly every plant. These machines occasion a large part of the load on the boiler plant, and since they operate continuously they waste a great amount of power, which could be saved by using a motor-driven compressor. The very extravagant hoist-engines with their small and long steam-lines, in which great condensation takes place, may likewise be replaced by electric hoists with a large resulting saving in power consumption.

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The flexibility of electric drive will appeal most to the mining companies, as soon as some of them become familiar with the system. Some properties operate several hoists, and undoubtedly more of them would like to do so if there was a convenient plan at hand to adopt. With electric power such a plan would be readily suggested. Electric drive for operating the roaster plants has already been adopted, but in all cases it has been necessary to install a generator for furnishing power to the motor, and usually both generator and motor were installed with excessive capacity, and as a result they are operated very inefficiently. When power from the line can be obtained, the motor losses will be the only ones in a roasting plant which will exist and the induction motor will be much better suited for efficient service in the dust-laden air of the furnace room. The lift pumps are in some instances operated by separate steam-engines, and at some plants the main engine which operates only eight or nine hours per day is a Corliss type, while that operating the pumps for twenty-four hours per day is in all plants in the district a slide-valve engine. Motor-drives for such pumps would therefore be well suited for such drive throughout the district.

There are many features about electric-drive which are especially well suited for the mines in this region, and the

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above mentioned ones are only a small part of the total. The cost of installation of a motor equipment will only amount to approximately a third of the cost of a steam power plant, and it may be easily moved to another plant, and if required, sold for a much greater proportion of the first cost than a steam plant can be sold for. In many instances it would hardly be a paying undertaking to attempt to move a boiler and engine plant from one mine to another after the plant had been in operation for some time, because the depreciation is so excessive.

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MOTOR DRIVE FOR THE MINE EQUIPMENTS

The motors which may be operated directly from the contemplated transmission system will have to be alternating current machines, and for some service they will not be as satisfactory as direct current motors. Those for operating the lift pumps should preferably be variable speed motors, because such would have better starting-under-large-load characteristics, and could also be operated more economically at different speeds. At most plants, however, the speed of the pumps may be maintained at a constant rate and when it shall be necessary to speed them up for draining a mine which has been closed down, a shift in pulleys may be provided for.

The present steam-driven compressor may be altered for constant speed drive and operated by a motor belted or geared to the present flywheels or to pulleys which may be installed on extended shafts which can be provided for. The pressure of the air supply can be regulated by some type of the various unloaders which are on the market. It will of course be advisable to disconnect some of the steam-connections. The motor will have to be chosen of a capacity much larger than will be required to operate the com-

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pressor with its average load, because the number of drills connected to the compressor is altered from time to time. The conditions of drillings operations at the different plants will have to govern such choice.

The standard mill of one hundred ton per eight hours capacity will require a motor of approximately seventy-five horse power capacity for driving according to the layout of the present mill equipments. A constant speed motor connected to the line shaft by belting to a clutch pulley will operate a mill equipment very satisfactorily. A new mill equipment might be arranged for group drive, but unless it were desired to operate the jigs at varying speeds such a system would not be recommended. Some power consumption might be saved by such an arrangement by overcoming some of the friction, but complications would result and, since the operation of a mill equipment necessitates the continuous operation of each machine, considerable confusion would result if a part of the number of machines ceased operation.

Satisfactory illumination of the plant and the underground workings of these mining properties will add considerably to their income. There will remain places where candle and oil lamps will have to be used, but the main lighting

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underground can be more efficiently done with incandescent lamps. Good illumination might result in ore veins being better and more closely followed up. The mine superintendent can have better supervision of his men when there is proper and enough light, just as the shop superintendent can, and the workmen underground will be enabled to do more efficient work with it.

At some of the mines the mill and the underground workings are lighted by open gasoline burners, and one place was visited where such a system was practiced where the pumps were hardly able to keep the water down so as to enable the men to do work and the pumps were installed under a roof which contained the engine and boilers. Such gasoline lamps as were mentioned above were in use, and there was only one means of escape from the shaft; certainly such conditions established a veritable deathtrap.

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ELECTRIC ROCK DRILLS

In a number of mines are operated some of the earlier types of electric rock drills. In several of the mines in the district a combination air and electric drill is being economically operated. The repairs on the earlier types of electric drills are quite prohibitive and less drilling is accomplished than with a standard air drill. The Temple-Ingersoll air drill consists of an equipment comprising a small motor driven air compressor on trucks. The compressor does not furnish a constant supply of air to the air drill which is used in connection with it, but a constant pressure is maintained on either side of the piston in the compressor cylinder, and two lengths of hose connect to either side of the air piston in the drill. This method operates the air drill with a pulsating air pressure. The motor consumes approximately five horse power, and as much drilling can be done with it as with an ordinary standard air drill. These drill equipments are giving good satisfaction, but they are heavy and cumbersome for easy handling. The old type of electric drill mentioned above uses a less horse power consumption. A number of tests with a number of them gave results showing that approximately two horse power was consumed in the motor.

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The average air drill consumed an amount of energy equalling approximately fifteen or eighteen horse power, and a satisfactory electric drill with its small amount of power consumption will cut down the operating expenses of the majority of the mines very considerably.

I desire to call to the attention of future graduates that there are a number of good opportunities for students at the university to make some practical tests among these mines which would work up well into graduating theses and result in furnishing the mining companies with much valuable information. Heretofore the mines in the district have in recent years been managed by men from various business pursuits. There have been clerks from stores, traveling salesmen, merchants, farmers, doctors, and office men, who have attempted to manage and superintend mining properties. At this period a number of the mines are being managed by men better fitted by training and experience to conduct such undertakings. These men are in a receptive state of mind concerning information affecting successful mining methods, and they will lend considerable assistance to those who will attempt to make interesting investigations.

The centrifugal pumps operating in the present mills ought to be tested for efficiencies, and the manager of one

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of the biggest properties stated to me that he would be glad to have such a test made at his plant, and that his company would be willing to lend considerable assistance. There is no doubt that many of these pumps could be tested under favorable conditions.

Another important series of tests could be made upon a number of steam hoists for steam consumption. Fairly efficient engines operate on thirty pounds of steam per horse power hour, but many of the steam engines operating hoists consume as much as ninety or one hundred pounds of steam and more per horse power hour. Reliable data on this point and comparative figures of cost would be very valuable to the miner.

Perhaps tests for effect of speed variation of the jigs upon the degree of ore separation could be successfully conducted. Considerable ore contents are lost in the tailings at some of the plants, and if a percentage of the present losses could be saved there would be a material gain financially to the mine. The customary mill man is incompetent to make an extensive test of this kind, and it remains for a student or a number of them to make such determinations.

A much discussed and argued problem is the required horse power consumption for operating the various sized air drills under different conditions of operation and install-

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ment of the feeder lines. Also the economy of operation of the different types of air compressors and the efficiencies of operation of the pressure regulators. I have in mind a small belted air compressor which was designed for operating two two and one-half inch air drills. It is so operating at present, and the power input for operating the two drills is more than forty-five horse power. There is an unloader on it which is supposed to cut down the power input when the pressure and supply in the tank is at a stated amount. The apparatus seems to be in good working order, but when it unloads the machine it does not unload it very much for at such a time the input is almost thirty-eight horse power.

Considerable waste of zinc occurs in roasting. Some of the metal is vaporized and escapes in the fumes. This condition is occasioned by too much heat being applied to a particle of the ore. Some of the ore is not roasted sufficiently to produce good separation. For proper separation different degrees of heat should be applied for different sized particles of ore, and this condition could be maintained if the ore which is fed to the roaster were of more uniform size. This would necessitate screening the ore and feeding to the furnace at different periods the screenings of one size or another. Pyrometers for determining the degree of heat in the furnace might be successfully applied

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to roasting methods, but they have never been used in the district.

Some valuable suggestions have been made to the mining corporations by graduate engineers, and such have led to economy in the mining methods at some of the plants. There have been some technical men working in the district, who have had many theoretical ideas which have not been practical. The men themselves were impractical and it seems that a poor impression of the value of good engineering has been entrenched in the minds of some of the operators. It remains for good engineers to overcome this prejudice, and I believe that the value of several good theses by undergraduates or post graduates will be considerably appreciated by these managers who are at the present time helping to put the lead and zinc mining industry of Wisconsin upon a paying commercial basis.

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APPROVED:

W. C. Beebe

Edwin B. Holden

J. W. Thurston,

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